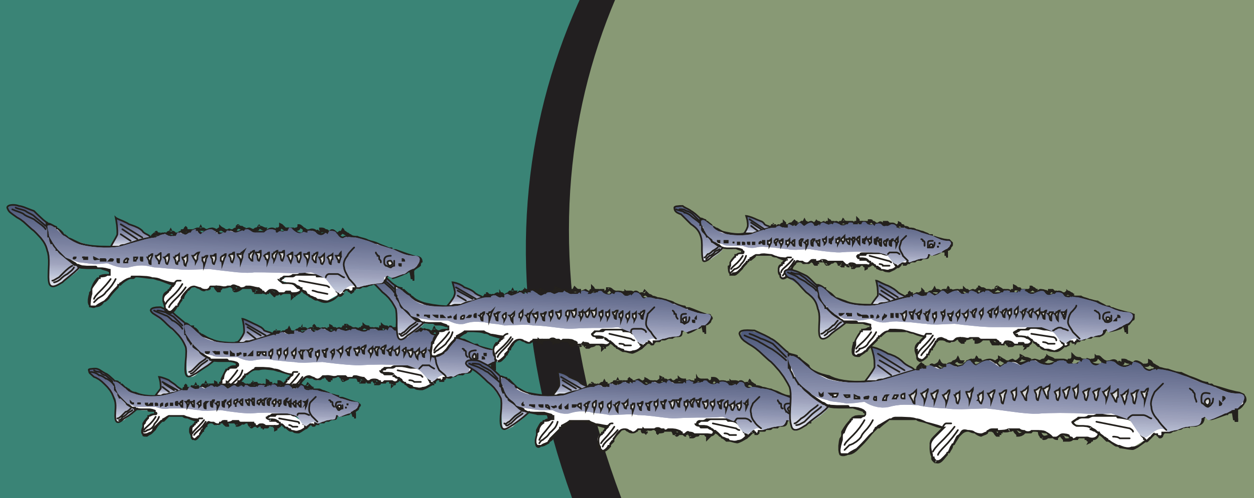
Review Draft

Columbia Basin White Sturgeon Planning Framework

Prepared for

The Northwest Power & Conservation Council

February 2013



PREFACE

This document was prepared at the direction of the *Northwest Power and Conservation Council* to address comments by the *Independent Scientific Review Panel (ISRP)* in their 2010 review of *Bonneville Power Administration* research, monitoring, and evaluation projects regarding sturgeon in the lower Columbia River. The ISRP provided a favorable review of specific sturgeon projects but noted that an effective basin-wide management plan for white sturgeon is lacking and is the most important need for planning future research and restoration.

The Council recommended that a comprehensive sturgeon management plan be developed through a collaborative effort involving currently funded projects. Hatchery planning projects by the Columbia River Inter-Tribal Fish Commission (2007-155-00) and the Yakama Nation (2008-455-00) were specifically tasked with leading or assisting with the comprehensive management plan. The lower Columbia sturgeon monitoring and mitigation project (1986-050-00) sponsored by the Oregon and Washington Departments of Fish and Wildlife and the Inter-Tribal Fish Commission also agreed to collaborate on this effort and work with the Council on the plan. The Council directed that scope of the planning area include from the mouth of the Columbia upstream to Priest Rapids on the mainstem and up to Lower Granite Dam on the Snake River. The plan was also to include summary information for sturgeon areas above Priest Rapids and Lower Granite.

A planning group was convened of representatives of the designated projects. Development also involved collaboration with representatives of other agencies and tribes involved in related sturgeon projects throughout the region. The process was aided by the organization of a series of three regional sturgeon workshops. A 2009 workshop identified a shared vision, goals, objectives and strategies for sturgeon conservation, management and mitigation efforts in the lower Columbia and lower Snake region. A 2010 workshop addressed critical uncertainties highlighted by the IRSP including natural recruitment limitations, genetic population structure, and sturgeon carrying capacity. A 2011 workshop addressed this basin-wide planning framework and sturgeon passage. A planning framework (this document) was drafted based on a review and synthesis of published and unpublished material regarding sturgeon in the region and proceedings of the workshops. The draft planning framework was distributed for review by other agencies and tribes with an interest in sturgeon within the region and revised based on comments from those parties.

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INTRODUCTION

1.1 BACKGROUND

The Columbia basin historically supported a very large and productive population of white sturgeon that ranged from the ocean upstream in the Columbia and Snake Rivers for hundreds of miles (Figure 7). White sturgeon had access as far upstream as Windermere Lake on the Columbia River in Canada (UCWSRI 2002) and Shoshone Falls on the Snake River in Idaho (IPC 2005). Columbia River white sturgeon also mixed in the ocean with white sturgeon from populations of other large rivers along the Pacific coast.

Sturgeons are uniquely adapted to large mainstem rivers like the Columbia and Snake (Beamesderfer and Farr 1997). These systems provide diverse habitats that are distributed in large-scale patterns corresponding to the surrounding topography. Habitats are extremely dynamic with large seasonal and annual variation. Distribution and abundance of prey and predator species varies widely in response to spatial and temporal patterns. Anadromous fishes, including salmon, eulachon, and lamprey historically provided tremendous seasonally-abundant food resources.

Figure 1. Large white sturgeon captured from a lower mid-Columbia River reservoir for population assessment.

Sturgeon evolved life histories ideally-suited to these large, diverse, and dynamic systems. Individuals ranged widely to take advantage of scattered and seasonally abundant resources. White sturgeon physiology allows them to move freely between fresh, brackish, and salt water further broadening their available resource base. Long distance movements are facilitated by their large size, shape and swimming ability which enable them to move through heavy current. Sturgeons are opportunistic predators that eat a variety of prey and switch as availability changes. They can withstand long periods of starvation during periods of low food availability or spawning migrations. Younger fish feed heavily on invertebrates in the benthic food chain where most production occurs in large river systems. Larger fish can consume large prey including adult salmon.

Unfortunately, many sturgeon adaptations have proven detrimental to sturgeon in today's altered system. Mainstem dams are barriers to white sturgeon, which do not consistently use fish ladders designed for salmon (North et al. 1993; Warren and Beckman 1993; Parsley et al. 2007). Dam construction has isolated groups of sturgeon in river segments that no longer provide the full spectrum of habitats needed to complete the life cycle. Access to scattered food and habitat resources is now blocked. Dam and reservoir operation have reduced seasonal and annual variability in flow which historically provided suitable spawning and rearing conditions for sturgeon and many of their prey. Impoundment has inundated many historical spawning habitats.

Distribution, abundance and productivity of white sturgeon have been severely reduced throughout the basin by construction and operation of the hydropower system (Beamesderfer et al. 1995; UCWSRI 2002; NPCC 2004). What was once a single population or a series of broadly overlapping metapopulations, has now been fragmented by dam construction into a series of subpopulations. The unimpounded lower Columbia downstream from Bonneville Dam continues to support a significant subpopulation but productivity has been impaired by lost access to thousands of miles of spawning and juvenile rearing habitat. Upstream from Bonneville Dam, status varies among impounded subpopulations from marginally productive to functionally extirpated. Subpopulations in many impoundments consist solely of aging cohorts of mature fish that are gradually declining as fish die and are not replaced. Unique headwater populations in the Kootenai and upper Columbia rivers are threatened or endangered with extinction and have been formally listed under the U.S. Endangered Species Act (ESA) or the Canadian Species at Risk Act (SARA). Only the longevity of individual fish has forestalled widespread extirpation.

White sturgeon are a highly-sought species in subsistence, commercial and recreational fisheries but harvest opportunities are now severely limited throughout the region. Historical commercial fisheries highlighted the huge production potential for white sturgeon in the Columbia River basin. With the advent of railroads for shipping and a large cannery industry, a Columbia River commercial fishery harvested over 18 million pounds of sturgeon in just six years around 1890. This harvest included 180,000 fish that averaged 150 pounds each. Unfortunately, sturgeon are notoriously vulnerable to overfishing due to their longevity and delayed age of maturity. The commercial fishery quickly mined out the standing stock and collapsed by 1900. The lower Columbia sturgeon population gradually rebuilt over the next 50-80 years to again provide substantial harvests by the 1960s and 70s. Harvest opportunities upstream from Bonneville Dam are currently sustained by only a few impounded subpopulations but fisheries are quite limited. Unfortunately, habitat conditions in impounded areas are no longer suitable to support sturgeon production adequate to provide a significant harvestable surplus.

White sturgeon in the Columbia Basin have long been a focus of fishery monitoring and management activities but first significant sturgeon research began in the 1940s when Bajkov (1949, 1951) described their biology. Hydropower mitigation efforts date back to 1940 when Ivan Donaldson of the U. S. Army Corps of Engineers began documenting early sturgeon passage efforts at Bonneville Dam (Warren and Beckman 1993). Dedicated assessment, research, mitigation and conservation efforts began only after the development of the Northwest Power and Conservation Council's Fish and Wildlife Program during the 1980s.

A variety of sturgeon projects have been implemented under the Fish and Wildlife Program since 1980. Extensive work has also been completed to support relicensing of private hydropower facilities throughout the region and formal listing of unique Kootenai and upper Columbia populations under U.S. and Canadian endangered species acts. Collectively, these efforts have now:

- provided a fundamental understanding of the biology, population dynamics and habitat requirements,
- determined the status of subpopulations throughout the region,
- identified key life stages and factors limiting most subpopulations,
- provided a firm scientific basis for fishery management consistent with current status, and
- explore the feasibility and effectiveness of protection, mitigation, restoration alternatives.

The region is now at a critical juncture with regards to white sturgeon. We have largely completed basic inventory and assessment work. We are now come to the point of making hard decisions on goals, strategies, investments and schedules for future sturgeon efforts. Decisions made on the direction of future sturgeon projects will determine white sturgeon status for decades to come. This document was developed to provide a solid framework for the next generation of sturgeon work throughout the region.

Figure 2. Photo of a juvenile white sturgeon (*Photo courtesy of the Freshwater Fishery Society of British Columbia)*.

1.2 Purpose of Framework

This framework document describes where we came from, what we know, and where we are going with respect to white sturgeon, in order to provide a firm foundation for future conservation, restoration, mitigation and management efforts throughout the Columbia River basin. This framework is an informational and guidance document intended for a broad audience, including co-management agencies and treaty tribes, action agencies and entities including the Northwest Power and Conservation Council (NPCC) and the Bonneville Power Administration (BPA), and other interested parties and stakeholders. This document is not a vehicle or agreement intended to supersede any regulatory or management responsibility, or authority by any party. The sturgeon framework represents the collective effort, expertise, and vision of a working coalition of parties with intersecting needs and interest. It is intended to inform current and future sturgeon-related planning and regulatory processes undertaken by parties throughout the region.

1.3 Plan Organization

This framework:

1. Summarizes the available information on sturgeon biology, status, fisheries, and limitations across the basin;
2. Describes a comprehensive regional vision and corresponding objectives and strategies based on a synthesis of ongoing efforts,
3. Details specific sturgeon programs in each area of the basin
4. Compares the efforts among areas in the context of the comprehensive regional objectives and strategies, and
5. Includes a series of overarching conclusions and recommendations based on the basin-wide assessment.

Plan chapters address:

- white sturgeon biology and life history (Chapter 2),
- Current status described in terms of distribution/spatial structure, abundance, productivity, and genetic stock structure (Chapter 3),
- Historical and current fisheries (Chapter 4),
- Limiting factors and threats that constrain status and use (Chapter 5),
- Comprehensive regional vision, goals, objectives and strategies (Chapter 6),
- Description of the nine recognized management units including population status, limiting factors, area-specific plans, programs, needs and uncertainties (Chapter 7),
- Basin-wide assessment comparing area-specific efforts and needs (Chapter 8), and
- Conclusions and recommendations (Chapter 9).

1.4 Planning Area & Management Units

This Framework encompasses the range of white sturgeon within the Columbia River Basin. Within the region, conservation, mitigation and management of Columbia River white sturgeon is complicated by their widespread distribution, fragmented population structure, and differences in status throughout their range. The broad distribution over hundreds of miles of river yields an overlapping patchwork of involvement and jurisdiction by a wide spectrum of interests, agencies, and authorities. Specifics of status and limiting factors for each subpopulation must be individually considered. Differences in status among subpopulations require different treatments and remedies.

Therefore, the Independent Scientific Review Panel (ISRP) recommended that the framework include area-specific sections or chapters that identify conservation, mitigation, management and research objectives, strategies, actions and schedules for different portions of the basin. This hierarchical organization will balance the need for comprehensive treatment with area-specific issues and actions. Different combinations of agencies and stakeholders will also be involved in the development of specific plans and programs in different areas. At the same time, conclusions about limiting factors, research and restoration needs and future work plans should be made with all dedicated sturgeon planning areas in mind. The guidance for subsequent implementation work plans, schedules and agreements in these areas must be incorporated into the basinwide plan.

This Framework recognizes nine sturgeon management units encompassing the historical distribution of white sturgeon in the Columbia and Snake rivers (Figure 3). Management units were defined during a facilitated work session held in connection with the development of this plan (Beamesderfer et al. 2011). The participants delineated these management units for white sturgeon in the Columbia River basin based on their expert opinion and the available information on population status, geography, habitat, and jurisdictional boundaries. Each unit encompasses a discrete section of the basin with common stock characteristics, habitat conditions, limiting factors, management strategies, and jurisdictional boundaries. Management units also generally represent areas of similar genetic characteristics that may warrant some consideration in implementation of sturgeon conservation and management measures.

The nine management units for Columbia and Snake River white sturgeon include: the Lower Columbia (below Bonneville Dam), Lower Mid-Columbia (Bonneville Dam to Priest Rapids Dam), Upper Mid-Columbia (Priest Rapids Dam to Grand Coulee Dam), Transboundary Upper Columbia (Grand Coulee Dam to Keenleyside Dam), Far Upper Columbia (Keenleyside Dam to Kinbasket Reservoir), Kootenay Lake and Kootenai River, Lower Snake (Ice Harbor Dam to Lower Granite Dam), Middle Snake (Lower Granite Dam to Hells Canyon Dam), and Upper Snake (Hells Canyon Dam to Shoshone Falls).

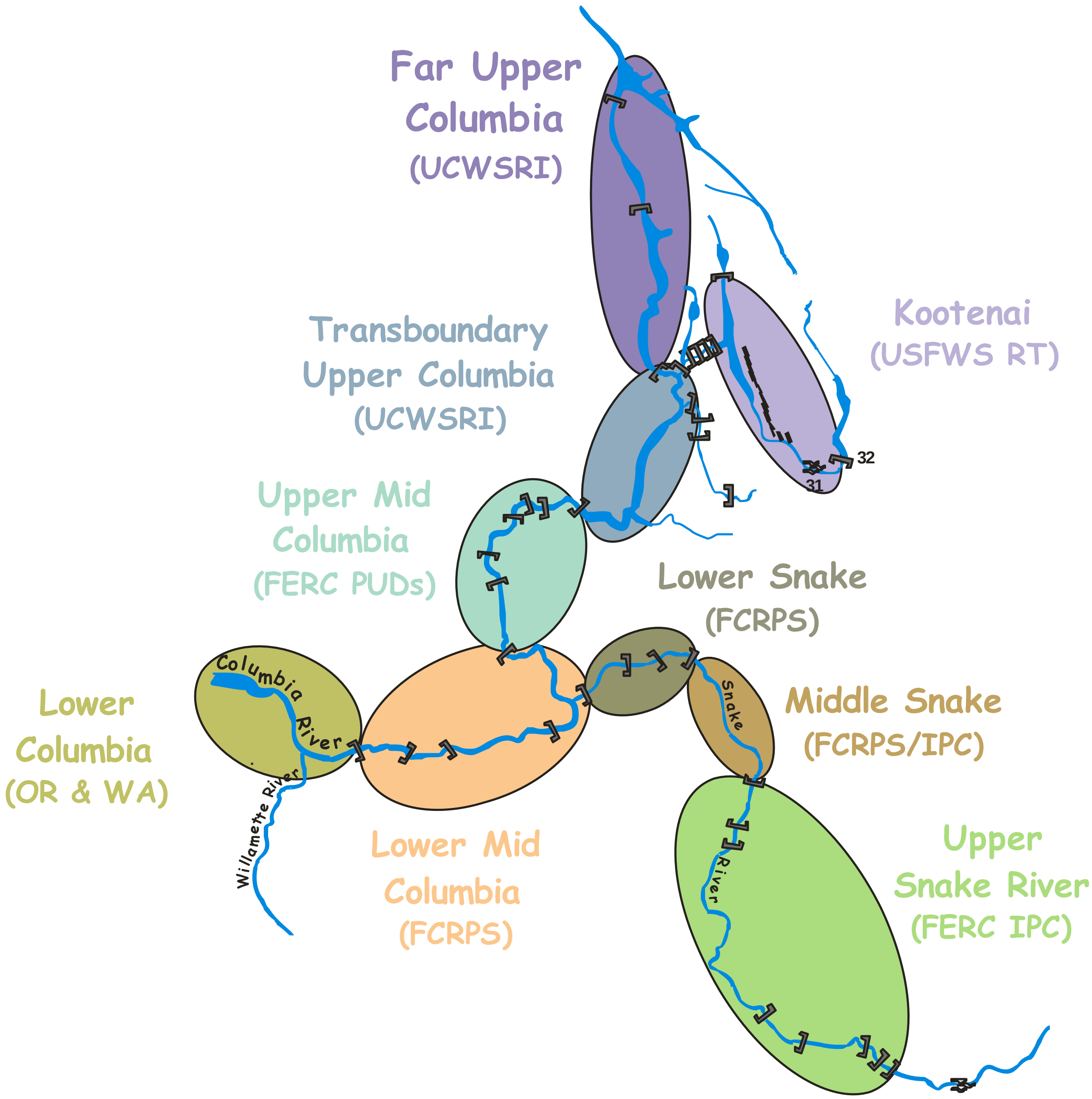


Figure 3. **Nine management units addressed by the framework. Related jurisdictions are also identified for each (OR = Oregon, WA = Washington, FCRPS = Federal Columbia River Power System, FERC = Federal Energy Regulatory Commission, PUD = Public Utility District, IPC = Idaho Power Company, USFWS = U. S. Fish and Wildlife, UCWSRI = Upper Columbia White Sturgeon recovery Initiative).**

1.5 A Brief History of Sturgeon Planning

This sturgeon planning framework represents a continuation of 30 years of dedicated sturgeon planning and project implementation efforts in the Columbia River basin.

In 1983, concern for sturgeon trends and the lack of information led the Columbia Basin Fish and Wildlife Council's Resident Fish Technical Committee and the Bonneville Power Administration to organize a regional workshop to address research needs. This was the first sturgeon work under the newly formed Northwest Power Planning Council's (now Northwest Power and Conservation Council) developing fish and wildlife program. Proceedings were published in 1984 (Fickeisen et al. 1984). The 1984 Fish and Wildlife Program subsequently highlighted the need for research to determine the impacts of development and operation of the hydroelectric power system on sturgeon. White sturgeon work and research program implementation plans were completed in 1985 (Fickeisen 1985a, 1985b). Objectives included: 1) assessment of current status, 2) evaluation of the need for protection, mitigation, and enhancement, 3) evaluation of potential methods for protection, mitigation, and enhancement, and development of tools to assess the effectiveness of efforts.

A regional White Sturgeon Management Framework plan was completed in 1992 by the Pacific States Marine Fisheries Commission (Hanson et al. 1992). Planning involved a wide range of policy and technical staff from State, Federal and Tribal fishery agencies from California, Oregon, Washington, and Idaho. This framework plan summarized the biological knowledge and management of white sturgeon throughout the Pacific States and provided guidance for further research and management. Goals included establishing and/or maintaining viable populations throughout the historic range, sustaining optimum benefits for diverse consumptive and on-consumptive uses, protection and enhancement of critical habitat, promotion of public awareness, and protection of the genetic integrity of local populations.

In 2010, the Northwest Power and Conservation Council and Independent Scientific Review Panel identified the need for the development of a comprehensive basin-wide planning framework to ensure that sturgeon projects are being implemented in a complementary and cost effective manner. A lower-mid Columbia sturgeon planning group expanded their effort to organize development of this framework through a collaborative process with sturgeon interests in other parts of the basin. This effort led to an annual series of sturgeon planning workshops from 2009-2013 culminating with the completion of this framework document.

An overview of this effort was provided to the various regional sturgeon interests in a workshop held in Troutdale, Oregon in 2012. Workshop participants were invited to participate in the framework development process, particularly to give input on critical uncertainties and needs for integration of efforts within and among different areas. Over 70 participants at the workshop identified opportunities and constraints to developing a basinwide management plan, data gaps at a global level, and ways to maximize the utility of the document. Most participants acknowledged that 1) there is value in an effort such as this, 2) the process is valuable, and 3) ancillary tools developed as part of this document could also be potentially useful.

1.6 PLANNING & POLICY GUIDANCE

The framework reflects guidance of a complex of plans, policies, and programs governing the activities of entities with related responsibilities and authorities. It is also expected that future plans, programs, actions, and priorities will be revised or adapted based on guidance provided in this sturgeon management plan.

1.6.1 Northwest Power and Conservation Council

Sturgeon mitigation for the Federal Columbia River Power System portion of the Basin, which includes the impounded lower Columbia and Snake rivers, is guided by the Northwest Power and Conservation Council (NPCC) and funded by the Bonneville Power Administration (BPA). The NPCC (formerly Northwest Power Planning Council) was established by the states of Idaho, Montana, Oregon, and Washington as authorized by the Pacific Northwest Electric Power Planning and Conservation Act passed by the U.S. Congress in 1980. 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 process.

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. Through the current Fish and Wildlife Program, specific measures are detailed in more than 50 subbasin plans developed locally and amended into the program by the Council. White sturgeon are included in the mainstem plan.

2009 Fish and Wildlife Program

White sturgeon planning, research, and restoration measures or goals have been included in all recent fish and wildlife programs. The 2009 Fish and Wildlife Program includes white sturgeon in its resident fish section and 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.

In 2007–2008, BPA and other agencies of the federal government also agreed to implementation commitments built on this broader planning foundation. These commitments will fund an extensive set of actions over the next 10 years to benefit listed and unlisted anadromous fish, resident fish, and wildlife across the Columbia River Basin. These include mainstem, estuary and tributary habitat, production, harvest, and monitoring actions. The agencies committed to these actions as part of the consultation resulting in the 2008 Biological Opinion for the Federal Columbia River Power System (FCRPS BiOp), and in the Columbia Basin Fish Accords (Accords) executed with certain Indian tribes and states. Thus, many areas of the Council's program already are covered by these multi-year implementation commitments. But these commitments do not cover all areas of the Program. Given the Council's obligation to adopt and oversee the implementation of the Program to protect, mitigate, and enhance all the fish and wildlife affected by the Columbia hydrosystem, including related spawning grounds and habitat, the Council is now adopting appropriate measures and will oversee the development of multi-year action plans for all areas of the Program.

2009 Program Mainstem Plan

The 2009 Fish and Wildlife Program included a section for sturgeon in the Mainstem chapter. The plan identifies a number of biological objectives including increases in spawning success and first year survival, reductions in predation mortality where significant, increases in abundance and productivity, sustainable harvest levels and opportunity, and reductions in population fragmentation. Specific strategies include studies that evaluate effects and mortality with respect to dam passage and removable spillway weirs. It also calls for an evaluation of the importance of connectivity among populations; assessment of population isolations and evaluation of the feasibility of mitigation.

The Mainstem Plan identifies the following vision: Hydrosystem operations, fish passage efforts, habitat improvement investments and other actions in the mainstem should be directed toward optimizing fish survival through the mainstem, largely by protecting, enhancing, restoring, and connecting 11 natural river processes and habitats, specially spawning, rearing, resting, and migration habitats for salmon, steelhead, sturgeon, and important resident fish populations. This will allow for abundant, productive, and diverse fish and wildlife populations. The plan also identifies the need to enhance the abundance and productivity of white sturgeon in the mainstem in order to rebuild and sustain naturally produced populations of sturgeon and sustain an annual harvest of sturgeon.

Sturgeon passage is also addressed. Ongoing changes in system operations and dam configuration affect the movement of white sturgeon in the lower Columbia. Studies indicate that white sturgeon move downstream through the reservoirs and pass downstream through spillways. The installation of removable spillway weirs at dams may affect downstream passage by white sturgeon via spillways. Bonneville and the Corps should:

- Study the effects on downstream passage of white sturgeon with and without removable spillway weirs
- Estimate mortality by size for fish that pass over spillways and removable spillway weirs and those that pass downstream through turbines. If significant mortality is occurring, identify and evaluate the feasibility of mitigation measures.
- In general, evaluate the importance of connectivity among sturgeon populations; assess whether the mainstem dams isolate sturgeon populations; and if so, evaluate the feasibility of mitigation

Program Sturgeon Expenditures

Approximately 4% ($9.5 million) of annual direct Fish and Wildlife Program expenditures of $246 million in 2012 were dedicated to white sturgeon (Figure 4). Kootenai sturgeon projects account for the majority of sturgeon-related expenditures ($6.5 million). The remainder is distributed among one general and six accord projects (Table 1). Note that this does not include costs of other sturgeon work funded by private power including the Public Utility Districts and Idaho Power Company.

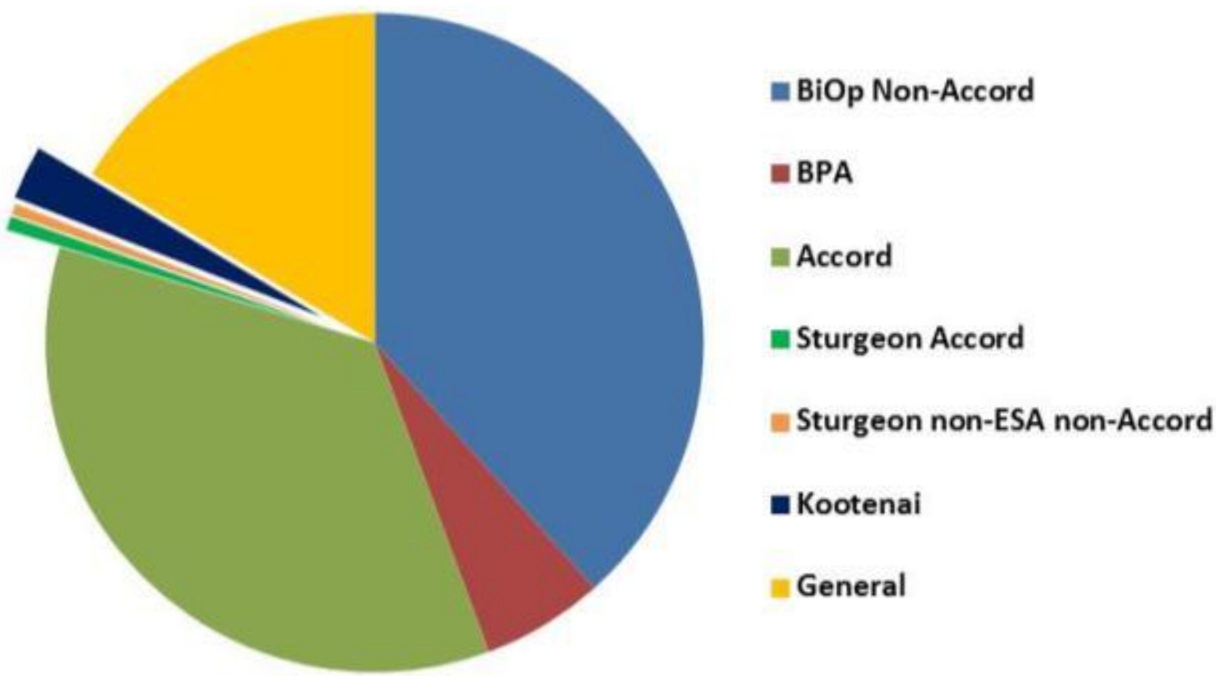


Figure 4. Sturgeon share of current spending under the Northwest Power and Conservation Council Fish and Wildlife Program.

Table 1. List of recent sturgeon projects and budgets identified in the Northwest Power and Conservation Council Fish and Wildlife Program and funded by the Bonneville Power Administration (source: cbfish.org).

Number	Project title	Fund	2010	2011	2012	2013
1986-050-00	Evaluate Sturgeon Populations in the Lower Columbia River	General	1,293	1,325	1,337	1,263
1988-064-00	Kootenai River White Sturgeon Aquaculture Conservation Facility	ESA	3,101	3,178	2,677	2,677
1995-027-00	Lake Roosevelt Sturgeon Recovery	Accord	489	501	506	506
2002-002-00	Restore Natural Recruitment of Kootenai River White Sturgeon	ESA	3,543	4,433	3,850	3,825
2007-155-00	Develop a Master Plan for a Rearing Facility to Enhance Selected Populations of White Sturgeon in the Columbia River Basin	Accord	100	186	227	177
2007-372-00	Lake Roosevelt Sturgeon Hatchery	Accord	256	263	263	263
2008-116-00	White Sturgeon Enhancement	Accord	--	--	465	793
2008-455-00	Sturgeon Management	Accord	128	139	152	138
2008-504-00	Sturgeon Genetics	Accord	26	42	49	66
2009-024-00	Kootenai White Sturgeon/Burbot Aquaculture Planning/Construction	ESA	1,100	--	--	--
	Totals	***ESA***	***7,744***	***7,611***	***6,527***	***6,502***
		Accord	***999***	***1,131***	***1,662***	***1,943***
		General	***1,293***	***1,325***	***1,337***	***1,263***
		All	***10,036***	***10,067***	***9,526***	***9,708***

1.6.2 States of Washington, Oregon, Idaho, Montana

Washington

The Washington Department of Fish and Wildlife (WDFW) manages white sturgeon as a species on its Priority Habitats and Species List. WDFW included white surgeon on this list after finding that the status of the species meets two criteria. The species is 1) a vulnerable aggregation susceptible to significant population declines within a specific area; and 2) it contains populations of recreational or commercial importance, and used for tribal ceremonial and subsistence purposes, whose biological or ecological characteristics make them vulnerable to decline in Washington or that are dependent on habitats that are highly vulnerable or are in limited availability.

Washington Fish and Wildlife Commission Policy C-3001 guides WDFW's management of the white sturgeon resource in the Columbia River downstream of Bonneville Dam and along the coast. WDFW shares management of this population with Oregon. The intent of the policy is to provide consistent management guidelines that promote a healthy population. The policy requires WDFW to manage the Lower Columbia River white sturgeon population with conservation and fishery management objectives that are consistent with a healthy population. This includes providing recruitment and regulatory protection to increase the abundance of the spawning population, managing with a precautionary approach, and managing for an annual combined sport and commercial harvest of white sturgeon to provide measurable population growth to achieve the goals of 1) fully seeded habitats and 2) full representation of each age class within the population.

WDFW shares responsibility for managing white sturgeon populations in the first three impoundments upstream of Bonneville Dam (the Zone 6 fishing area) with Oregon and the Columbia River Treaty Tribes (collectively, the Parties) through the *U.S. v. Oregon* Management Agreement. The intent of the Parties is to manage sturgeon populations in the Zone 6 fishing area to provide long-term sustainable harvest opportunities for Indian and non-treaty fisheries. Through the agreement, the Parties have committed to continue ongoing studies to estimate present and optimum population levels, life history characteristics, recruitment, spawning potential, and appropriate sturgeon fishing sanctuaries. The Parties have also committed to pursuing enhancement activities, along with the necessary funding, for sturgeon populations in the Zone 6 fishing area.

Finally, white sturgeon populations in the Columbia River between Priest Rapids Dam and the Canadian border, and from the mouth of the Snake River to the Idaho border fall entirely within Washington State waters and are subject to the its management authority which is shared with Indian tribes.

Oregon

The Oregon Department of Fish and Wildlife (ODFW) manages Columbia River white sturgeon in cooperation with Washington and the Columbia River Treaty Tribes. Oregon has identified white sturgeon as a conservation priority based on their ecological, economical, and social importance. The species is not formally designated as sensitive by Oregon, but has been identified as a “data gap” species (ODFW 2009).

In 2009, the ODFW initiated a planning process for white sturgeon as directed by the Oregon Native Fish Conservation Policy (ONFCP) that specifically calls for conservation plans for species with “high public interest or economic or other impact on the local community” (ODFW 2003). The conservation planning effort is predicated on the concept that locally adapted populations provide the best foundation to sustain populations of naturally produced native fish (ODFW 2003).

Oregon initially focused sturgeon planning efforts on the lower Columbia River population and adopted a Lower Columbia River and Oregon Coast White Sturgeon Conservation Plan (ODFW 2011) in August 2011. Currently, the lower Columbia River white sturgeon population segment is not at risk and the conservation plan provides a framework to manage and conserve this important species while ensuring sustainable harvest opportunities and other ecological and societal benefits in perpetuity. Consistent with the Oregon Native Fish Conservation Policy, the specific goals of the Lower Columbia River and Oregon Coast White Sturgeon Conservation Plan are to: 1) avoid any substantial reductions in the lower Columbia River white sturgeon population segment; 2) maintain a naturally reproducing white sturgeon population segment in the lower Columbia River that makes full use of natural habitats, providing ecological, economic, and cultural benefits to Oregon residents; and 3) provide sustainable commercial and recreational fishing opportunities.

Oregon is current engaged in a State Conservation planning effort for impounded sturgeon populations from Bonneville Dam to the Washington border in McNary Reservoir.

Idaho

The Idaho Department of Fish and Game (IDFG) goal for Snake River white sturgeon is to preserve, restore, and enhance populations capable of providing sport fishing opportunities. By statute, the IDFG manages the fish and wildlife of the state for the public (Idaho Code Section 36-103). The IDFG 2007–2012 Fisheries Management Plan (IDFG 2007) lists five guiding principles governing white sturgeon management within their historical range.

1) Status of existing sturgeon populations will be determined and monitored, and factors suppressing populations will be evaluated.
2) Sport fishing will be regulated commensurate with population status.
3) Habitat loss or degradation will be opposed and measures will be promoted to improve limiting factors.
4) Importation of non-native sturgeon will be restricted to avoid potential genetic or disease impacts to native stocks.
5) Sturgeon populations may be supplemented with native stocks where necessary to maintain future management options, to research survival rates, to utilize suitable rearing habitat where natural recruitment does not exist, or to create fishing opportunity.

IDFG developed a Management Plan for the Conservation of Snake River White Sturgeon to provide policy direction to staff and to ensure the long-term persistence of the species within in its historical range. This management plan will be implemented in consultation with other state and federal agencies, tribal agencies, Idaho Power Company, and other interested stakeholders. The plan reflects Idaho Fish and Game Commission policy and direction to the IDFG and includes management philosophy expressed as goals and objectives. The objectives of the management plan include providing for coordinated management of white sturgeon in the Snake River, providing for an orderly and sustainable no harvest recreational fishery, facilitating data collection for stock assessments, integrating and defining the role of artificial propagation, increasing public awareness through information and education, and obtaining public acceptance and compliance for the plan.

IDFG is also closely involved with a collaborative conservation and recovery effort for the federally-listed Kootenai River population which occurs in waters shared with Canada and Montana, and also involves the U.S. Fish and Wildlife Service, the Kootenai Tribe of Idaho, the Province of British Columbia, U. S. Army Corps of Engineers, and the Bonneville Power Administration.

Montana

White sturgeon occur in Montana in only 21.7 miles of the Kootenai River from Kootenai Falls downstream to the Idaho/Montana border. Montana Fish, Wildlife & Parks (MFWP) has designated Kootenai River white sturgeon as a Tier I Species, which is a species with the greatest need for conservation. MFWP's goal for Kootenai River white sturgeon is to protect and ultimately restore the population to a sustainable level capable of providing sustainable recreational angling opportunities within the state of Montana. MFWP has management authority (Montana Code Annotated 87-1-201) of this species in the Montana portion of the Kootenai River, but MFWP recognizes that a collaborative conservation effort with Idaho, Kootenai Tribe of Idaho, and British Columbia, Canada, is required to recover this endangered species. MFWP supports the implementation of coordinated regional conservation measures with other state, provincial, federal, and tribal agencies, and other vested stakeholders. These measures include flow and temperature management at Libby Dam, implementation of a conservation aquaculture program that includes releases of juvenile white sturgeon in Montana, applied research and monitoring activities to identify limiting factors, and habitat restoration efforts in the lower Kootenai River that will promote conditions favorable to early life stage survival.

1.6.3 Columbia River Indian Tribes

Currently, the United States government officially recognizes 14 groups of affiliated tribes in the U.S. portion of the Columbia River Basin. These are the Colville, Kalispel, Spokane and Yakama confederated tribes in Washington; the Kootenai, Coeur d'Alene, Nez Perce, Shoshone-Bannock and Shoshone Paiute tribes in Idaho; the confederated Salish and Kootenai tribes in Montana; and the Grande Ronde, Warms Springs, Umatilla and Burns Paiute confederated tribes in Oregon. There are three tribal groups, known as First Nations, in the Canadian portion of the basin: the Okanagan, whose homeland is along that river; the Ktunaxa, whose homeland is in the east Kootenay region in the Columbia headwaters area; and the Kinbasket, an eastern band of the Shuswap nation, whose homeland is in the upper Fraser River area north and west of the Columbia. A fourth First Nation group, the Sinixt, is distributed among other tribal groups in the West Kootenay area, where their homeland was along the Arrow Lakes. The Sinixt people, also known as Lakes Indians, have relatives among the Colville Confederated Tribes.

Treaty Indian Tribes

The Nez Perce Tribe, the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes of the Warm Springs Reservation of Oregon, and the Confederated Tribes and Bands of the Yakama Nation have reserved rights to harvest anadromous fish that were guaranteed in 1855 treaties with the United States. These four tribes joined together in 1977 to renew their authority in fisheries management. Out of that effort, the tribes created the Columbia River Inter-Tribal Fish Commission (CRITFC), a coordinating and technical organization to support their joint and individual exercise of sovereign authority.

Non-Treaty Indian Tribes

Of the 10 non-treaty Indian tribes in the U.S. portion of the Columbia River basin, the Kootenai Tribe of Idaho, Spokane Tribe of Indians, and the Colville Confederated Tribes have been actively engaged in sturgeon conservation and management. In 1990, the Kootenai Tribe of

Idaho initiated the Kootenai River White Sturgeon Study and Conservation Aquaculture Project to preserve the genetic variability of the population, begin rebuilding natural age class structure with hatchery-reared fish, and prevent extinction while measures are implemented to restore natural production of fish. The tribe has been successfully incubating, hatching, raising and releasing sturgeon using the eggs and sperm of adult fish taken from the river – and later returned. Subsequent monitoring shows the juveniles are surviving.

The Colville Confederated Tribes and the Spokane Tribe of Indians have taken an active role in the Lake Roosevelt White Sturgeon Recovery Project, a multi-agency project that is responsible for assessing the white sturgeon population in Lake Roosevelt. The project receives funding from the Bonneville Power Administration through direction of the Northwest Power Act and the Northwest Power and Conservation Council's Columbia Basin Fish and Wildlife Program to recover native populations of fish and wildlife in hydropower-impacted regions.

The participation of Canadian First Nations in sturgeon recovery and planning is largely through the Canadian Columbia River Inter-Tribal Fish Commission (CCRIFC), who is a partner in the Upper Columbia White Sturgeon Recovery Initiative.

1.6.4 U.S. v. Oregon / Columbia River Fishery Management Plan

The four Columbia River Tribes that entered into treaties with the federal government in 1855 reserved and "secured" their timeless right to harvest salmon for economic, cultural, and subsistence purposes at "usual and accustomed" fishing grounds of the Columbia River and its tributaries. These rights were upheld in the landmark case *United States v. Oregon*, and subsequently, these four tribes gained a co-management role through the Columbia River Fishery Management Plan (CRFMP).

U.S. v. Oregon Agreement

U.S. v. Oregon, originally a combination of two cases, *Sohappy v. Smith* and *U.S. v. Oregon* (302 F. Supp. 899), legally upheld the Columbia River treaty tribes reserved fishing rights. Although the Sohappy case was closed in 1978, *U.S. v. Oregon* remains under the federal court's continuing jurisdiction serving to protect the tribes' treaty reserved fishing rights. Defendants are the states of Oregon, Washington and Idaho. Plaintiffs are the United States, the four Columbia River treaty tribes and the Shoshone-Bannock Tribe whose status in the case is different than that of the four tribes.

In his 1969 decision, Judge Robert C. Belloni ruled that state regulatory power over Indian fishing is limited because, in 1855 treaties between the United States and the Nez Perce, Umatilla, Warm Springs and Yakama tribes, these tribes had reserved rights to fish at "all usual and accustomed" places whether on or off reservation.

According to Belloni's ruling, states may regulate only under certain conditions and in compliance with certain standards, including:

- States may regulate only when reasonable and necessary for conservation.
- States must offer proof that particular regulations are necessary to accomplish conservation.

- Regulations must not discriminate against the Indians.
- Regulations must be the least restrictive.
- Fisheries cannot be managed so that little or no harvestable fish reach upstream areas where most of the Indian fishery takes place.
- Treaty fishing rights may not be subordinated to some other state objective or policy.
- The protection of treaty fishing rights must be a state regulatory objective coequal with its fish conservation objectives.
- Indians may be permitted to fish at places and by means prohibited to non-Indians.
- The tribes are entitled to "a fair and equitable share" of the resource.

In 1974 Judge George Boldt decided in United States v. Washington (384 F. Supp. 312) that Belloni's "fair and equitable share" was, in fact, 50 percent of all the harvestable fish destined for the tribes' traditional fishing places. The following year, Judge Belloni applied the 50/50 standard to *U.S. v. Oregon* and the Columbia River. Judge Boldt's decision also affirmed tribal rights to self-regulation when in compliance with specific standards.

The intent of the states of Oregon and Washington and the Columbia River Treaty Tribes (the Parties) under *U.S. v. Oregon* is to manage sturgeon populations in the Zone 6 fishing area to provide long-term sustainable harvest opportunities for Indian and non-treaty fisheries. The current status of the sturgeon population is the key factor in determining appropriate harvest levels. The Parties commit to continue ongoing studies to estimate present and optimum population levels, life history characteristics, recruitment, spawning potential, and appropriate sturgeon fishing sanctuaries.

Columbia River Fishery Management Plan

The Columbia River Fishery Management Plan (CRFMP) was accepted as partial settlement to *U.S. v. Oregon*. The purpose of this management plan is to provide a framework within which the *U.S. v. Oregon* Parties may exercise their sovereign powers in a coordinated and systematic manner in order to protect, rebuild, and enhance upper Columbia River fish runs while providing harvests for both treaty Indian and non-Indian fisheries. Specific to sturgeon, “the intent of the Parties is to manage sturgeon populations in the Zone 6 fishing area to provide long term sustainable harvest opportunities for Indian and non-treaty fisheries. Parties commit to continue ongoing studies to estimate present and optimum population levels, life history characteristics, recruitment, spawning potential.” With respect to sturgeon fisheries management, “the Parties commit to pursuing enhancement activities, along with the necessary funding, for sturgeon populations in the Zone 6 fishing area. Activities considered will include, but not be limited to: artificial propagation, transplantation from other areas, and flow augmentation.”

Sturgeon Management Task Force

Oregon, Washington and the Columbia River Treaty Tribes established a joint Sturgeon Management Task Force (SMTF) in 1986. The SMTF meets regularly to review sturgeon management issues and set harvest guidelines for the upcoming year. Information reviewed includes recreational, commercial and subsistence landings for each reservoir between

Bonneville and McNary Dam. Estimates of encounters in non-retention recreational activities are also considered. The Sturgeon Management Task Force determines annual harvest guidelines for each Zone 6 reservoir. The effectiveness of harvest management is measured relative to a three-year rolling average of the guidelines. Annual harvest guidelines may be adjusted to account for cumulative overages/underages. The treaty catch may be taken in gillnet, setline, platform or hook-and-line fisheries. Oregon, Washington, and the Columbia River Treaty Tribes agree to undertake a review of sturgeon management regulations. The effect of size limits, sanctuaries and other regulations on the harvest guidelines is estimated.

The Parties have committed to pursuing enhancement activities, along with the necessary funding, for sturgeon populations in the Zone 6 fishing area. Activities considered will include, but not be limited to, artificial propagation, transplantation from other areas and flow augmentation. The Parties agree that funding for ongoing studies to estimate present and optimum population levels, life history characteristics, recruitment, spawning potential and appropriate sturgeon fishing sanctuaries is essential to successfully managing these populations.

1.6.5 Canada

The administrative responsibility for the management of the white sturgeon and all freshwater species belongs with the British Columbia Ministry of Environment. The federal agency, Fisheries and Oceans Canada, ensures that recovery planning is consistent with federal acts, policies and regulations, including federal policy for the management of fish habitat. The Canadian Columbia River Inter-tribal Fisheries Commission is assisting the Ktunaxa and Shuswap Nation governments in their consideration of necessary recovery measures.

To address ongoing declines of white sturgeon and promote recovery, the Province of British Columbia has implemented a series of conservation measures since the 1990s. Beginning in 1994, commercial and sport harvests of sturgeon were closed and First Nations people voluntarily stopped their sustenance harvests. This important step allowed more fish to survive and reproduce and helped to slow the decline of some stocks.

In 2000, an Upper Columbia White Sturgeon Recovery Initiative was initiated in Canada with an agreement signed by Fisheries and Oceans Canada, BC Environment, BC Fisheries and BC Hydro. UCWSRI grew into a transboundary collaboration of over 25 partners from government, First Nations and American tribes, industry, environmental groups and others with a common interest in the future of white sturgeon in the upper Columbia River in British Columbia and Washington. Recovery planning began after a review of upper Columbia white sturgeon found that young fish were becoming alarmingly rare. A sturgeon recovery plan was completed by the UCWSRI in 2002 identifying goals and recommending methods for achieving them. The original recovery plan has been revised and a new draft was completed in February of 2013.

1.6.6 Listing Status

U. S. Endangered Species Act (ESA)

The unique headwater population of Kootenai River white sturgeon was listed as endangered in 1994 in response to population declines caused by near-total recruitment failure (Duke et al. 1999). A recovery plan was subsequently developed and related efforts are ongoing. The U.S. Fish and Wildlife Service's issued biological opinions 2000 and 2006 concerning hydrosystem operations that affect listed Kootenai River white sturgeon. These opinions include specific objectives for this listed species.

Lower and mid-Columbia white sturgeon are not currently listed under the Endangered Species Act or subject to any current plans or petitions for listing. Hence, neither population is specifically subject to biological opinions, recovery plans, habitat conservation plans, or other plans. Thus, Columbia River white sturgeon were not considered in the 2008 Federal Columbia River Power System Biological Opinion (FCRPS BiOp).

Green sturgeon are addressed by the 2008 FCRPS BiOp, but their Columbia River distribution is limited to the estuary. Actions affecting mainstem flow and habitat conditions identified in the BiOp for the benefit of ESA listed salmonids have the potential to indirectly affect mid-Columbia River sturgeon, but implemented or planned salmon alternatives have not and are not expected to significantly improve production of mid-Columbia River sturgeon populations.

Species at Risk Act (SARA)

In November 2003, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) determined that white sturgeon populations in Canada should be considered an endangered species. In August 2006, the Government of Canada added white sturgeon populations from the Kootenay, Nechako, Upper Columbia, and Upper Fraser rivers to Schedule 1, the list of species protected under the Species at Risk Act (SARA). Listing under SARA provides for protection of individuals of the species and their critical habitats. All white sturgeon populations, whether listed or not listed, will continue to be carefully managed under SARA and the Fisheries Act. SARA also requires that recovery planning be undertaken for listed species, and a comprehensive recovery strategy is in development for all of these populations. This planning process is based on the existing recovery initiatives for each of the populations. The recovery goal for white sturgeon is to ensure the long-term viability of naturally reproducing populations within the species' natural range, and to restore opportunities for beneficial use, if and when feasible. To achieve this goal, a series of objectives and general strategies have been identified, including specific recovery measures, research, and ongoing monitoring.

State Listing Status

The state of Washington includes white sturgeon on its Priority Habitats and Species List, meeting criteria as a species comprised of aggregations vulnerable to significant population declines and containing populations of recreational or commercial importance, and used for tribal ceremonial and subsistence purposes, whose biological and ecological characteristics make them vulnerable to decline in Washington and dependent on habitats that are in limited availability.

The state of Oregon has identified white sturgeon as a conservation priority based on their ecological, economical, and social importance. The species is not formally designated as sensitive on the state list, but has been identified as a "data gap" species (ODFW 2009).

The state of Idaho considers white sturgeon, including those inhabiting waters shared with Oregon, to be a species of concern (IPC 2005). The IDFG recognizes three separate categories of white sturgeon populations in the Snake River:

1) Core conservation populations defined as self-sustaining that support sport fisheries with regular natural recruitment and all age/size classes represented.
2) Conservation populations defined as reaches with existing white sturgeon populations and sport fisheries, but with infrequent or no natural recruitment and unbalanced age/size structure. These reaches may receive recruitment from downstream drift or may have received hatchery supplementation in the past, but lack the flow, water quality, and/or physical habitat characteristics to meet all life history requirements in most years.
3) Sportfish populations – defined as suitable large river waters outside the native distribution where hatchery-produced white sturgeon can provide or have provided diversity to existing fisheries.

The state of Montana has categorized white sturgeon as Conservation Tier I, a classification for species with the greatest conservation need. No special classifications currently exist for white sturgeon in the state of Washington.

1.6.7 FERC Licensing

Sturgeon mitigation issues in upper mid-Columbia River and Snake River reservoirs operated by Public Utility Districts (PUDs) or investor-owned electric utilities, such as Idaho Power Company, fall under the purview of Federal Energy Regulatory Commission (FERC) license requirements (Table 2). Under the expected terms of their new license agreements, the responsible parties will implement sturgeon conservation and mitigation actions in portions of the upper mid-Columbia and Snake Rivers.

Table 2. Mainstem dams affecting sturgeon licensed by the Federal Energy Regulatory Commission.

Licensee	Projects
Grant County PUD	Priest Rapids, Wanapum
Chelan County PUD	Rock Island, Rocky Reach
Douglas County PUD	Wells
Idaho Power Company	Hells Canyon, Oxbow, Brownlee, Swan Falls, C. J. Strike, Bliss, Lower Salmon Falls, Upper Salmon Falls, and Shoshone Falls

Grant County PUD

Grant County PUD developed a White Sturgeon Management Plan for the Priest Rapids Project (Priest Rapids and Wanapum reservoirs) (GCPUD 2008). The goal of the management plan is to promote growth of the population in the project area to a level that is commensurate with the available habitat by year 30 of the new license. To meet this goal, Grant County PUD is proposing a supplementation program to increase the population through use of hatchery-reared fish, fish that have been captured in the lower Columbia River for direct release into the reservoir or other methods recommended through a collaborative effort with relicensing stakeholders represented in a Priest Rapids Fish Forum established as part of the license. A new license was issued in April 2008.

Chelan County PUD

Chelan County PUD completed a Rocky Reach White Sturgeon Management Plan in February 2006. The overall goal of this plan is to promote white sturgeon population growth in the [Rocky Reach] Reservoir to a level commensurate with the available habitat based on monitoring results. This is to be accomplished by meeting the following objectives: 1) increasing the population of white sturgeon in the Reservoir through implementing a supplementation program; 2) determining the effectiveness of the supplementation program; 3) determining the carrying capacity of available habitat in the Reservoir; and 4) determining potential for natural reproduction in the Reservoir, then adjusting the supplementation program accordingly. A new license was issued February 2009.

Douglas County PUD

Douglas County PUD developed a White Sturgeon Management Plan for the Wells Project. The goal of this plan is to increase the white sturgeon population in the Wells Reservoir to a level that can be supported by the available habitat consistent with its carrying capacity based upon a program involving supplementation activities, monitoring of results, and adjustment to the supplementation program as warranted by the monitoring results. Consistent with the other Mid-Columbia PUDs, the Wells Project is seeking settlement agreements with tribal, state and federal resource managers to be included as a part of their new FERC License. These discussions are ongoing, with the new License scheduled to be issued in 2013.

Idaho Power Company

Idaho Power Company developed a White Sturgeon Conservation Plan as part of its relicensing efforts for several of its hydroelectric projects. Idaho Power Company projects along the middle Snake River include Hells Canyon, Oxbow, Brownlee, Swan Falls, C. J. Strike, Bliss, Lower Salmon Falls, Upper Salmon Falls, and Shoshone Falls dams. Idaho Power Company submitted the White Sturgeon Conservation Plan to FERC in August 2005. In May 2006, the FERC approved conservation measures for four segments of the Snake River including Shoshone Falls, Upper and Lower Salmon Falls, Bliss, and C.J. Strike. The conservation plan includes protection, mitigation and enhancement measures developed by the White Sturgeon Technical Advisory Committee, established in 1991 to provide technical guidance with white sturgeon research activities undertaken by the Idaho Power Company during its relicensing efforts. The conservation plan is a guidance document meant to assist with implementation of protection, mitigation, and enhancement measures for Snake River white sturgeon populations impacted by Idaho Power Company’s hydroelectric projects. The geographic scope of the conservation plan includes the Snake River from Shoshone Falls downstream to Lower Granite Dam.

2 SPECIES DESCRIPTION

2.1 TAXONOMY & MORPHOLOGY

There are 25 sturgeon species worldwide and eight of these occur in North America (Bemis and Kynard 1997). White sturgeon (*Acipenser transmontanus*) are the largest freshwater fish species in North America (Page and Burr 1991). They reach lengths up to 20 feet (Scott and Crossman 1973) and weights up to 1,800 lbs (Hart 1973). 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).

Sturgeon are characterized by a cartilaginous skeleton, a persistent notochord, and lack scales (Scott and Crossman 1973). All sturgeon have five rows of bony plates called 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 is used to distinguish white sturgeon (11 - 14 dorsal, 36 - 48 lateral, and 9 - 12 ventral scutes) from other sturgeon species (Scott and Crossman 1973). Bajkov (1955) also described white sturgeon with seven rows of scutes including 3% of the specimens collected downstream from Bonneville Dam.

Sturgeon possess a tube-like mouth and four barbels located on the ventral surface of a hard protruding snout. Several authors have noted a geographic basis for snout dimorphism in white sturgeon (Crass and Gray 1982; Brannon et al. 1986). Landlocked forms appear to have more pointed snouts than sturgeon 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.

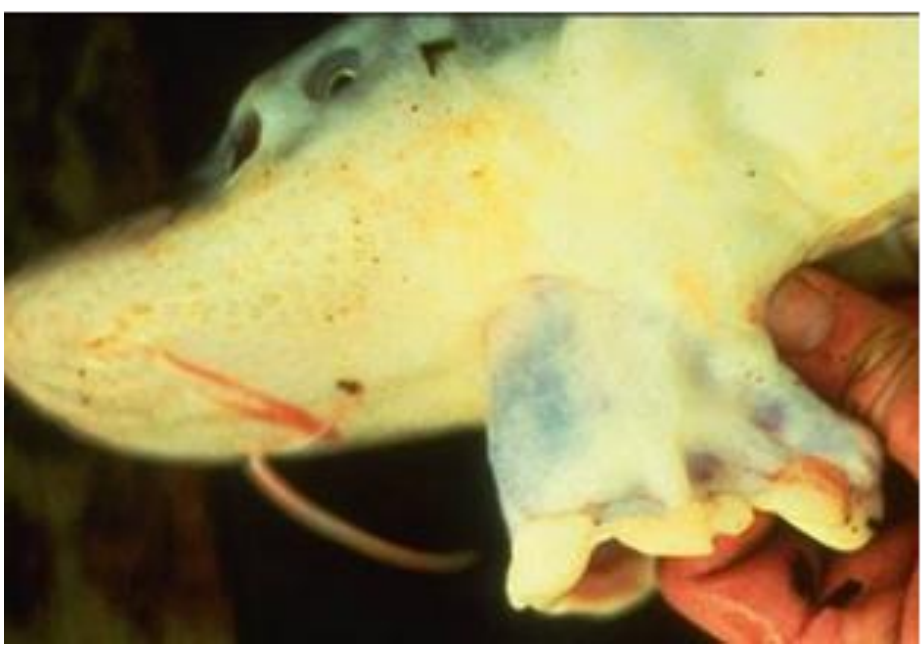


Figure 5. Eversible proboscis of a white sturgeon.

Green sturgeon (*Acipenser medirostris*) are also found in the Columbia River, but are restricted to coastal areas (Scott and Crossman 1973, Brown 1989, Adams et al. 2002, 2007, Beamesderfer et al. 2007). Green sturgeon are rarely observed upstream from the estuary. Green sturgeon originate from spawning populations in the Sacramento, Klamath and other California and Oregon coastal rivers but do not reproduce in the Columbia. Green sturgeon can be readily distinguished from white sturgeon by barbels which are located equidistant between the nose and the mouth or closer to the mouth in green sturgeon (vs. closer to the nose in white sturgeon) and by the position of the anus which is in line with the posterior insertion of the anal fins in green sturgeon (vs. posterior to the posterior insertion of the anal fins in white sturgeon) (Figure 6).

Figure 6. Comparisons of morphology between white sturgeon (left) and green sturgeon (right). ***Photos courtesy of Ruth Farr, Oregon Department of Fish and Wildlife.***

2.2 Range

White sturgeon inhabits large rivers, estuaries, and the near-shore ocean from Ensenada, Mexico to the Aleutian Islands in Alaska (Figure 7). This species spawns in freshwater but is amphidromous, meaning they spawn in freshwater but can regularly move between fresh and saltwater to feed (Scott and Crossman 1973; Bemis and Kynard 1997; Wydoski and Whitney 2003). Both amphidromous and freshwater-resident population occur. Substantial populations spawn in the Columbia, Fraser, and Sacramento-San Joaquin river systems (Scott and Crossman 1973, Lee et al. 1980, Lane 1991). White sturgeon make extensive use of coastal bays and estuaries throughout their range and occasionally enter smaller coastal rivers where no spawning population is present. The ocean distribution of these populations is sympatric, but only occasional movement of tagged fish has been observed among the three main river systems (DeVore et al. 1999).

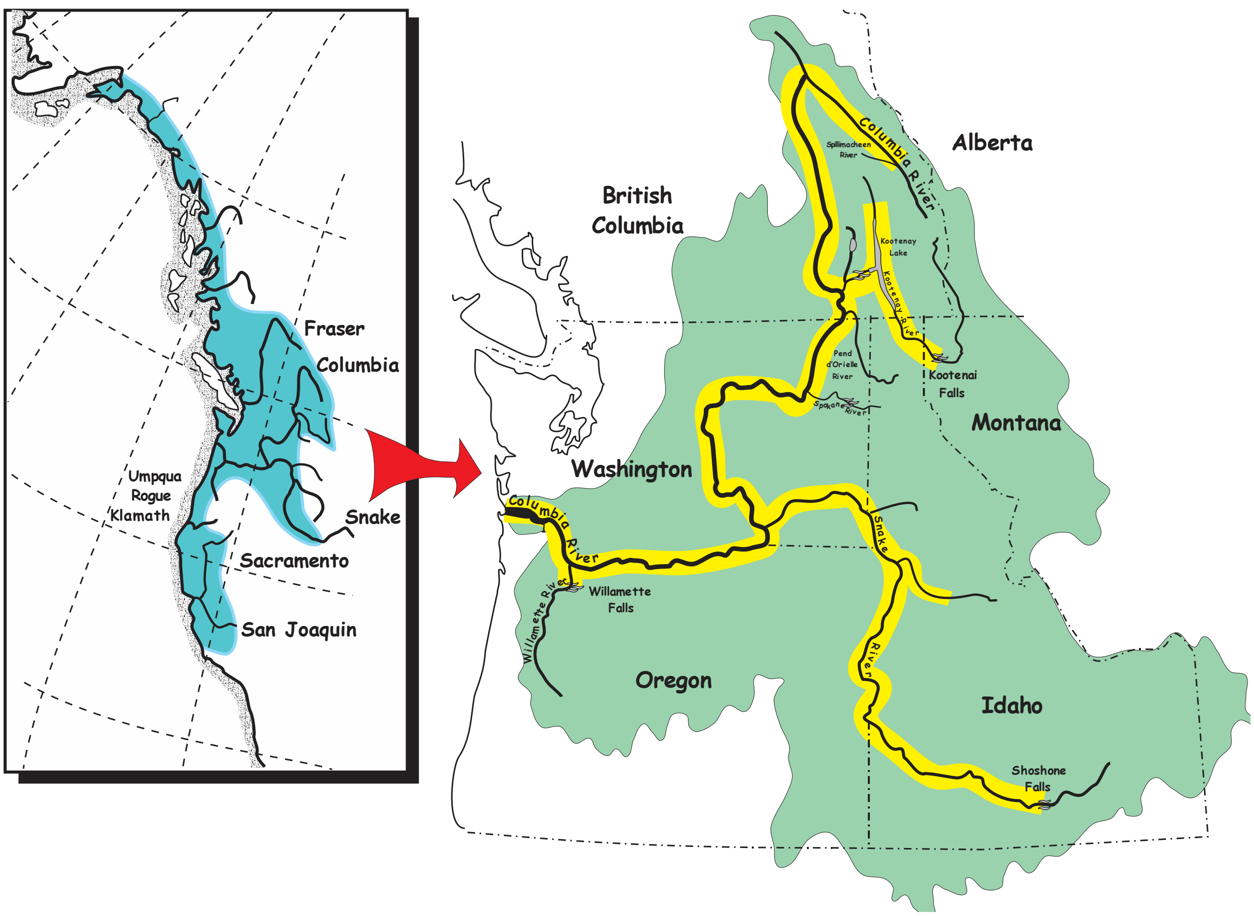


Figure 7. Historical range of white sturgeon.

2.3 LIFE HISTORY

White sturgeon can be characterized as "periodic reproductive strategists" (Winemiller and Dailey 2002). Periodic strategist species typically live for long periods of time and experience low mortality after the juvenile stages. Fish mature late in life, are iteroparous, and produce many offspring. The periodic strategy is believed to have evolved in response to highly stochastic environments, in which mortality of young may be very high and highly variable. In these environments, successful reproduction may depend on specific cues or conditions, which may be relatively rare events. The long life and high fecundity of periodic strategists are adapted to take advantage of infrequent periods of high water and increased biological productivity, ensuring long-term persistence of the population.

Life history terminology used in this document, beyond the larval stage, is as follows. Age-0 begins after larval metamorphosis is complete and ends, arbitrarily, on 31 December of their first year of life. White sturgeon are considered juveniles from age-1 until they are able to enter estuarine and marine environments (approximately 96 cm FL; McEnroe and Cech 1985; ODFW, unpublished data). The sub-adult stage begins when white sturgeon can enter estuarine and marine environments and ends at sexual maturity.

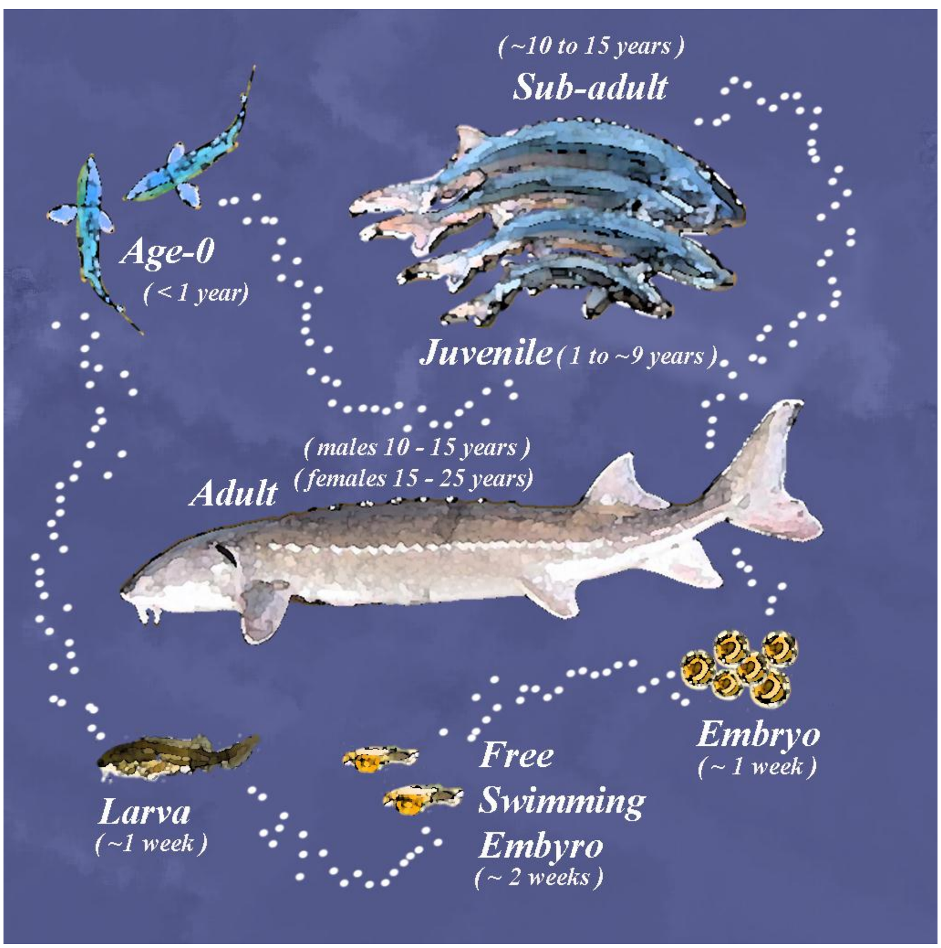


Figure 8. White sturgeon life cycle including embryo, free-swimming embryo, larva, age-0, juvenile, sub-adult and adult life stages.

2.3.1 Spawning

Behavior

White sturgeon are broadcast spawners, releasing their eggs and sperm into the water column over boulder and cobble substrates where fertilization occurs (Hanson et al. 1992; Parsley et al. 1993). Fish gather in aggregations to spawn and several males typically 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 appear to display more localized movements. The extent of sturgeon spawning migrations prior to development of the hydropower system is uncertain. It appears likely that fish using marine waters, the estuary and lower river migrated some distance upstream to find suitable spawning habitats.

Timing

Spawning occurs during spring when water temperature is between 10 and 18°C (Hanson et al. 1992; Parsley et al. 1993). Sturgeon spawning often occurs later in the year and over shorter time periods in upper basin and northern populations, in part due to colder spring. However, sturgeon in the Arrow Lakes Reservoir and Kootenai River populations spawn at temperatures well below presumed optima that no longer occur (or never occurred) in those systems during the typical spawning time frame due to thermal effects of upstream hydropower dams. Optimum spawning temperatures for these populations may be lower than those identified for Sacramento River white sturgeon.

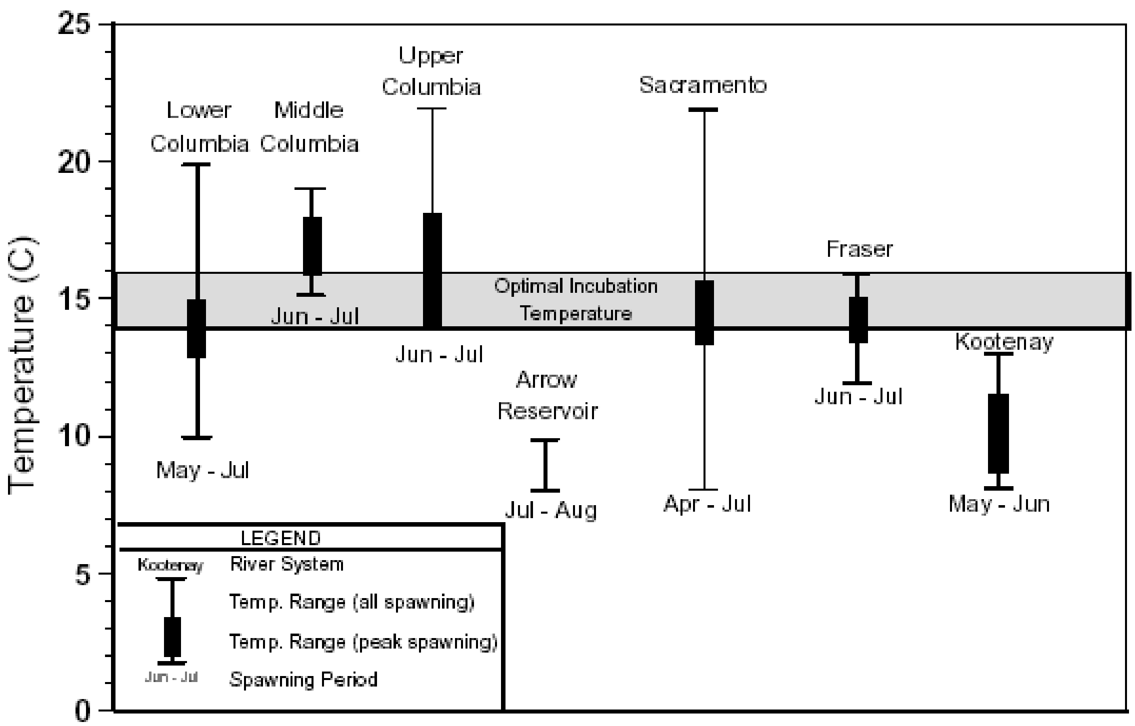


Figure 9. Water temperatures associated with spawning by white sturgeon (Anders and Beckman 1993; Parsley et al. 1993; Hildebrand and Mckenzie 1994; RL&L 1995, 1996a, 1996b, 1996c, 1997a, 1998a, 1998b, 1998c, 1998d, 1999a, 1999b, 1999c, 1999d; Perrin et al. 1999, 2000).

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 (vitellogenesis) have also been documented in other sturgeon species (Kazanskii 1963; Kazanskii and Molodtsov 1973; Williot et al. 1991; Chebanov and Savelyeva 1999).

Habitat Requirements

Spawning typically occurs over cobble or rock substrate in turbulent areas associated with moderate to high water velocities. Sites are often in close proximity to deeper, slower-moving “staging” or “resting” areas.” Documented spawning sites include river confluences, rapids near large eddies, and dam tailraces. Preferred sites provide specific combinations of water velocity, turbulence and substrate but the factors that determine site selection and subsequent spawning success are poorly understood. Conditions at spawning sites have been documented but many alternative sites that appear to provide similar conditions are not utilized. It appears that sites are chosen based on interacting combinations of conditions rather than any specific parameter by itself. It’s one of those “the whole is greater than the sum of the parts” kinds of things. Sites suitable for successful spawning appear to be in limited supply and their availability has also been much reduced by river impoundment which has inundated many section of river.

<u>Substrate</u>. White sturgeon typically spawn over substrates of large cobble and rock where fine material has been cleared from interstices by the current (Scott and Crossman 1973). Smaller substrate also appears to be used by populations in the Sacramento, Fraser, and Kootenai/y systems, but data on those systems are either limited (Sacramento and Fraser) or suggest that use of fine substrate is not successful (Kootenai; Duke et al. 1999; Anders et al. 2002). Evidence to support the active selection of clean, coarse substrates is available for many 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 (Baker 1980; Bruch and Binkowski 2002; UCSWRI 2002; Smith and Baker 2005).

Incubating white sturgeon embryos are sensitive to exposure to fine sediments. Based on replicated in-situ sediment exposure trials, (Kock et al. 2006) reported that Kootenai River white sturgeon embryo survival was reduced to 0–5% under sediment covers of 5 and 20 mm, compared to mean survival of > 80% in the controls. Embryo mortality was also positively correlated with duration of sediment cover, and was significantly lower for embryos covered for 4 d (50% survival) or 7 d (30% survival) than for those covered for 9, 11, or 14 d (15–20% survival). Sediment cover also significantly delayed hatch timing and decreased the mean length of surviving larvae. These authors suggested that sediment cover may be an important early life stage mortality factor in rivers where white sturgeon spawn over substrates of sand or fine sediment.

It is unclear whether white sturgeon actively select areas of suitable substrate or select velocity cues that are correlated with substrate type. For instance, Kootenai white sturgeon appear to be spawning over unsuitable substrates apparently in response to other cues.

Velocity. High water velocity is a key attribute of spawning site selection. High velocities scour fine material that can smother eggs, exclude potential predators, and may help disperse eggs, embryos, and larvae. Mean water column velocity measured in confirmed spawning areas typically ranged between 0.5 and 2.5 m/s (Parsley et al. 1993; Parsley and Beckman 1994). Habitat suitability criteria developed for U.S. populations of white sturgeon identified 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 velocity of > 1.5 m/s to provide for sturgeon spawning in the Upper Columbia River.

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 m/s) have been reported for Kootenai white sturgeon (Paragamian et al. 2001). However, spawning in that system does not lead to recruitment because eggs are deposited in depositional areas unsuitable for egg survival (Anders et al. 1993; 2002; Kock et al. 2006).

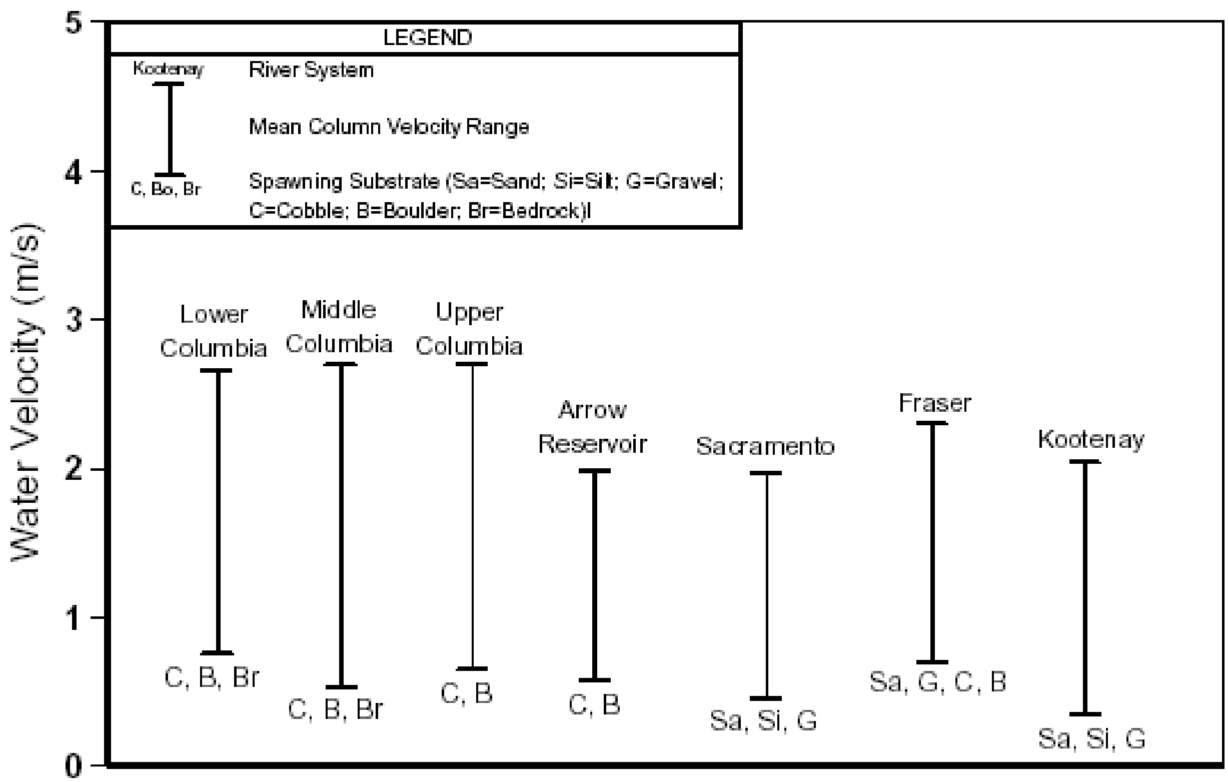


Figure 10. Substrates and water velocities associated with sturgeon spawning site selection (Parsley et al. 1993; RL&L 1996a, 1996b, 1996c; Perrin et al. 2000).

Turbulence. Turbulence is a feature common to all documented spawning sites in the Columbia and Snake rivers. Turbulence involves complex mixing of currents with irregular patterns of water direction and velocity. It is strongly related to velocity and river discharge with higher velocities and flows generally create larger areas of turbulence. Turbulence is relatively easy to distinguish but difficult to measure. Consequently, its relationship to sturgeon spawning site selection is well known but poorly documented. Turbulence is created by horizontal or vertical relief or structure and is associated with channel complexity which produces cascades, eddies, or confluences.

Figure 11. White sturgeon spawning site in Waneta eddy at the mouth of the Pend Oreille River on the transboundary reach of the upper Columbia River.

<u>Turbidity</u>. Spawning is often associated with periods of high turbidity but it is unclear whether the success of spawning or recruitment depends on turbidity or this condition is simply correlated with other conditions associated with spawning. White sturgeon have been reported to spawn in turbid waters at high flows (Parsley et al. 1993; Perrin et al. 2003). However, effects of fine sediments suspended in the water column on reproductive success remain uncertain. Turbidity and river discharge are often highly correlated in unregulated rivers and often to a lesser extent in regulated rivers. Benefits of high turbidity during spring runoff may include reduced predation on sturgeon eggs, embryos, or larvae by visual piscivores. Flow regulation has reduced turbidity during most times of the year (except during annual high water events), which could enhance predation rates on early life stages of white sturgeon (P. Anders, Cramer Fish Sciences, personal communication).

<u>Depth</u>. Although white sturgeon are thought to spawn near the river bottom at a wide range of water depths (0.5–50 m), above a presumed but unknown minimum threshold, depth does not appear to be a highly critical factor influencing spawning site selection. Maximum depth ranged in areas of observed white sturgeon spawning, including: 3–5 m at the Pend 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). However, the degree to which spawning is occurring at the surface, throughout the water column, or near the substrate remains unclear. In an effort to characterize depth suitability for white sturgeon spawning, Parsley and Beckman (1994) proposed a relationship between suitability and depth that on a scale from 0 to 1, predicted a suitability value of 0 for depths $\leq$ 2m, increased suitability values between 0 and 1 for depths from 2 to 4 m, and spawning suitability of 1 (100% suitable) for all depths from 4 to 25 m.

2.3.2 Incubation & Early Life History

Early life stages include embryo, free swimming embryo, and larva (Balon 1984, Parsley et al. 2002, van der Leeuw (2006). The embryo stage begins at fertilization and ends after incubating embryos hatch. The free-swimming embryo stage begins at hatch and ends with the beginning of exogenous feeding. The larval stage begins with exogenous feeding and ends when the fins and organs are fully developed. Corresponding behavioral phases include incubation, dispersal, and hiding.

The incubation phase typically lasts 7–14 days, depending on temperature (Wang et al. 1985, Conte et al. 1988). Based on laboratory experiments with white sturgeon collected from San Francisco Bay, Wang et al. (1985, 1987) reported that: 1) the optimum temperature range for incubation was between 14 and 16°C; 2) successful incubation was observed from 10 to 18°C; 3) temperatures in excess of 18°C caused substantial abnormalities; and 4) temperatures below 14°C extended incubation and hatching times, but did not result in developmental abnormalities. Anders and Beckman (1995) reported 98% mortality (129 of 132) of all eggs collected from The Dalles Pool during 1987 at water temperature of 64°F (18°C) and warmer. However, these authors also documented egg mortality in water 55 to 63°F (13-17°C), indicating additional egg mortality factors. RL&L (1997a) incubated wild-caught eggs using in situ capsules in the Columbia River in B.C. and showed generally lower hatch success at temperatures exceeding 18°C.

A dispersal phase, dispersal, occurs immediately after hatching when they leave the substrate and free-swimming embryos are suspended in the water column (Brannon et al. 1987; Conte et al. 1988). In the lower Columbia River, dispersing embryos have been collected at depths of 4–58 m over a variety of substrates (Parsley et al. 1993). This behavior distributes sturgeon into available rearing habitats. This 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). White sturgeon larvae in the Columbia River below Bonneville Dam are transported over 175 km downstream from spawning areas (McCabe and Tracy 1994). However, Kynard and Parker (2005) reported a longer intermittent swim up and drift phase for Kootenai sturgeon free embryos that began generally after 10 days, suggesting possible differences in evolved behaviors that may be related to food availability differences between rivers. The dispersal style of Kootenai sturgeon is different from that of white sturgeon populations in other long rivers, like the Sacramento and Columbia rivers, and likely adapts slow-growing young Kootenai sturgeons to rearing in a short river with low food abundance (Kynard and Parker 2005).

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. However, microhabitat use patterns are likely dictated to some degree by the presence, absence, and abundance of particular microhabitat features, which can differ among rivers (P. Anders, Cramer Fish Sciences, personal communication).

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, embryo incubation, and larval concealment areas (Anders et al. 2002; Parsley et al. 2002; Kock et al. 2006). Larvae are particularly vulnerable to predation at the swim up stage. Thus, 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) can reduce survival. The dispersal phase might also transport larvae into downstream reservoirs where food may be scarce or where 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.

Emerging evidence suggests that the timing and behavior during these transitions may differ not only by geographic region, but also according to the availability and spatial distribution of food resources required for each exogenously feeding early life stage. Canadian researchers have found that white sturgeon may actually exhibit a hatch-hide type response (McAdam et al. 2008). That is to say, the early life history sequence is hatch, hiding by free-swimming embryos without a dispersal phase, followed by active external feeding. Dispersal, or drift, may occur between hatching and hiding if suitable hiding spots are not encountered at the time of hatch (McAdam et al. 2009). Drift likely occurs later at the initiation of active feeding, to allow larvae to move to areas with sufficient food resources. Drift at hatch may be indicative of poor habitat conditions, whereas active external feeding drift may simply be a means of moving to areas where food is locally abundant (S. McAdam, British Columbia Ministry of Environment, personal communication). In the Sacramento River, white sturgeon appear to exhibit a two-step dispersal pattern. Kynard and Parker (2005) noted a weak dispersal behavior for Sacramento River population in newly hatched free-swimming embryos that lasted only a few hours to a few days, followed by hiding and active external feeding through larval stages and a longer, stronger dispersal post-metamorphosis (Kynard and Parker 2005).

Figure 12. Juvenile white sturgeon at approximately 2-3 months of age.

2.3.3 Food & Feeding

White sturgeon are primarily benthic feeders on invertebrates and fish. Diet varies with fish size and local prey availability. Because of very large differences in size over their lifespan, different size classes of sturgeon exploit, affect, and are limited by very different components of the aquatic community. The body shape and mouth structure of white sturgeon are ideally suited to bottom feeding. Food items are detected with chemo- and electro-receptors located on four sensory barbels and the snout rather than by sight alone (Brannon et al. 1985; Buddington and Christofferson 1985). However, white sturgeon are often surprising selective in their choice of food. Individuals are also regularly observed actively pursuing prey throughout the water column (S. King, ODFW, personal communication).

Juveniles typically rely on benthic invertebrates. Juvenile white sturgeon (<80 cm total length) in the lower Columbia River have been reported to feed mainly on invertebrates, with amphipods (*Corophium sp*.) being the most-often selected prey items (McCabe et al. 1993; Romano et al. 2002). McCabe et al. (1993) also noted that a substantial portion of the diet for white sturgeon of this size class in the lower Columbia consists of eulachon eggs, isopods, mysids, Asian clams, snails, and small fish (such as sculpins and assorted fry). Diets of juvenile white sturgeon from other areas of the Columbia Basin also included significant numbers of Chironomids along with large numbers of other benthic organisms such as mollusks and amphipods (Sprague et al. 1993). Stomach contents were collected from 41 juvenile Kootenai River white sturgeon in Idaho and BC during 2002 most commonly included Chironomid larvae spp. were the most common diet item by weight and number (Rust et al. 2003; Rust et al. 2004).

White sturgeon develop more diverse diets as they grow, as allowed by the available prey base. Sub-adults consume a variety of benthic organisms. Larger white sturgeon are increasingly piscivorous. Larger sturgeon in the lower Columbia River 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. Fish dominate the adult sturgeon diet through most of the year (50%); in winter, benthic invertebrates become dominant with clams being the most important item (12-41%) (Semakula and Larkin 1968; McKechnie and Fenner 1971; Scott and Crossman 1973).

Diet composition can vary substantially throughout the year as white sturgeon take advantage of seasonally abundant prey items, especially where anadromous and estuarine fishes are available. The lower Columbia River white sturgeon population feeds heavily on the eulachon during their spawning run in 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.

Dams that block migration into the upper Columbia and Snake rivers eliminated a food source that was likely important to the pre-development white sturgeon population. This food source was particularly important in upstream, oligotrophic areas, given that anadromous salmon accumulate over 95% of their biomass in the ocean, setting the stage for substantial energy and nutrient subsidies when they return to their natal habitats to spawn (Schindler et al. 2003). Anadromous prey were most abundant in the fall and may have provided an important energy source for overwintering, with significant energetic or nutritional implications for sturgeon spawning frequency and fecundity (Hildebrand and Birch 1996).

Food of sturgeon in these upper basin reaches is now considerably less diverse. For instance, Partridge (1980, 1982, 1983) collected information on stomachs of Kootenai sturgeon turned in by anglers. Plant material and Chironomid larvae occurred in most samples. Other items included fish parts, small clams, snails, leeches, mayfly larvae and stonefly. Mysid shrimp entrained from Arrow lakes were reported to be an important food item among sturgeon in the upper portions of the Transboundary reach downstream from H. L. Keenleyside Dam. Lepla and Chandler (1998) found that diet in the Bliss reach of the upper Snake commonly included chironomids, caddisfly larvae, snails, clams, and shrimp.

2.3.4 Movements & Habitat Use

During early life stages, white sturgeon in the lower Columbia River use a variety of habitats. Age-0 white sturgeon in the lower Columbia River prefer deep (9–38 m), low velocity areas where substrate particle sizes are small (e.g., sand; Parsley et al. 1993). Parsley et al. (1993) noted that more than 99 percent of juvenile white sturgeon (> 15 cm) downstream from Bonneville Dam were encountered over sand, and that they seemed to prefer the main river channel where risk of stranding would have been minimized in natural free flowing rivers. Juvenile and sub-adult white sturgeon occupy a wide variety of depths (2–40 m; Parsley et al.

1993; Parsley et al 2008). Juvenile white sturgeon preferentially used low velocity areas over sandy substrates (Parsley et al. 2003) while others exhibited diel depth preferences. Parsley et al. (2008) reported the average daylight depth for juvenile and sub-adult white sturgeon to be 21 m and average night depth to be 15 m. Though fish observed by Parsley et al. (2008) exhibited this diurnal/nocturnal migration, depths used by individual fish were highly variable, with some fish occupying depths < 5 m and others remaining at depths > 10 m. Juvenile and sub-adult white sturgeon are known to use both main and off channel habitats in the lower Columbia River (Parsley and Popoff 2004; Parsley et al. 2008), and prefer those habitats with moderate riverbed roughness and slope (Hatten and Parsley 2009).

Juveniles use a wide variety of habitats. In lower gradient areas including the 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 in British Columbia, slough and large backwater habitats adjacent to the mainstem provide important rearing habitats (Lane and Rosenau 1995); these types of habitats are unavailable in some portions of the Columbia River, for example, between Keenleyside Dam and Lake Roosevelt.

Habitat use of subadults and adults varies with habitat availability. 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 range widely, presumably in search of scattered or mobile food resources. Many white sturgeon movement and migration patterns appear related to feeding. In the lower Columbia River below Bonneville Dam, white sturgeon have been observed migrating upstream in the fall and downstream in the spring (Bajkov 1951; Parsley et al. 2008). This pattern was also noted for white sturgeon inhabiting free flowing stretches of the Hanford Reach (Tri-Cities, Washington, upstream to Priest Rapids Dam) located further upstream in the Columbia River (Haynes et al. 1978).

In riverine environments white sturgeon seem to prefer free flowing stretches (Bajkov 1951; Haynes et al. 1978), though they are also known to inhabit lower velocity lacustrine habitats (Haynes et al. 1978). Sturgeon are typically distributed throughout mainstem reservoirs but are most abundant in the more-free flowing upper reaches. The exception is in very large reservoirs such as Lake Roosevelt where sturgeon make relatively little use of most of the reservoir downstream from the river-reservoir transition zone.

Fish are more typically 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, or can take advantage of the patchy distribution of vertebrate and invertebrate prey items. 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.

2.4 LIFE HISTORY PARAMETERS

2.4.1 Size

White sturgeon as large as 20 feet in length and 1,800 pounds in weight have been historically documented In Canada's Fraser River (Scott and Crossman 1973). The biggest recorded sturgeon in the Columbia system was a 1,500-pound fish caught in the Snake River (Anderson 1988). This historical record is replete with photos of large sturgeon from the Columbia River in the 600 to 900 lb range.

Currently, fish up to about 10.5 feet total length and 400 pounds have been measured in stock assessment sampling (Table 3). Total length is typically about 11% greater than fork length (Beamesderfer 1993). Larger fish are periodically reported by anglers but have proven difficult to sample with stock assessment gear. However, fish over 8 or 9 feet in total length are rare in the Columbia system.

As with most fish, weight increases exponentially with increasing length (Figure 13). Considerable differences in condition factor have been documented between lower and upper basin populations. Condition factor is an index of skinniness or plumpness based on weight for a given length. An average individual in the lower Columbia typically weighs two or more times that of a similarly-sized fish from the Kootenai river. Lower condition factors in the upper basin are typically attributed to lower productivity and food availability.

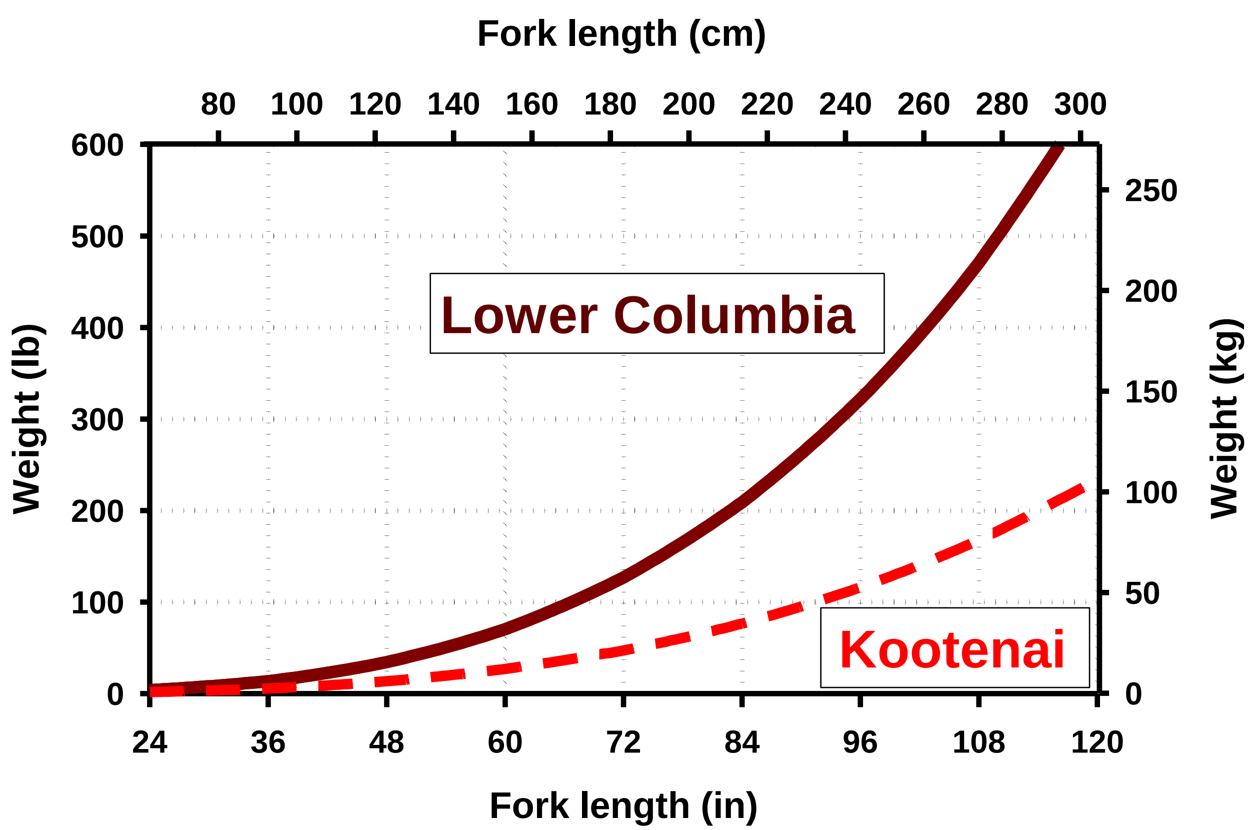


Figure 13. Average length-weight relationship for white sturgeon based on lower Columbia River (DeVore et al. 1995) and Kootenai samples (Paragamian et al. 2005).

Table 3. Size and age parameters for white sturgeon populations throughout the Columbia and Snake river basins.

Location	Maximums Size (FL cm)	Weight (kg)	Age (yr)	Length-weight[a] α	β	Condition Wr[b] (%)	Age-length relationship[c] L_{inf} (FL cm)	k	t0	Reference
Lower Columbia										
Estuary – Bon. Dam	263					117				Beamesderfer et al. 1995
Estuary – Bon. Dam				1.05E-05	2.96		310	0.027	-2.4	DeVore et al. 1995
Lower Mid-Columbia										
Reservoirs			104							
Bonneville Reservoir	269					103				Malm 1979
Bonneville Reservoir	292	161		3.11E-06	3.19	99	311	0.022	-2.4	Beamesderfer et al. 1995
The Dalles Reservoir	276	180		1.35E-06	3.38	96	340	0.023	-2.4	Beamesderfer et al. 1995
John Day Reservoir	254	111		2.40E-06	3.26	100	382	0.022	-2.4	Beamesderfer et al. 1995
Upper Columbia										
Transboundary (wild)	271	152	65	1.54E-06	3.23		256	0.027	-3.0	RL&L 1996
Transboundary (hat.)	130	16	10	2.75e-6	3.20		156	0.069	3.3	Golder 2009
Snake										
Hells Canyon 1972-75	280	144		1.14E-06	3.31	83				Lukens 1985
Hells Canyon 1982-84				6.50E-06	3.43					Lukens 1985
Hells Canyon			56							Coon et al. 1977
Hells Canyon	228			3.42E-06	3.09	88	296[d]	0.047[d]	-0.7[d]	Lepla 2003
Hells Canyon upper				1.27E-06	3.27					Lepla 2003
Upper	270	96	45	3.00E-07	3.61	91				Cochnauer 1983
Swan Falls - Brownlee				2.25E-06	3.16		290[d]	0.046[d]	-1.1[d]	Lepla 2003
Bliss Reach	261	117		3.20E-06	3.13	100				Lepla & Chandler 1998
Kootenai										
River (wild)	244	101		1.66E-06	3.26	97				Partridge 1983
River (wild)	211					77				Beamesderfer 1993
River (wild)	254	108		4.20E-06	3.12					Paragamian et al. 2005
River (wild)			80+				276	0.015	-3.1	Paragamian & Beamesderfer 2003

[a] $Weight = \alpha \; Length^{\beta}$

[b] The Relative weight index (Wr) describes fish condition relative to a standard weight equation that represents the 75th percentile of populations (Beamesderfer 1993)

[c] $Length = L_{inf} \, [\, 1\text{-}exp^{-k\,(age - t0)}]$

[d] Parameters based on total length.

2.4.2 Age & Growth

Large sizes of white sturgeon are the product of rapid growth rates and longevity. Ages as large as 104 have been estimated for Columbia River white sturgeon but fish over 70 or 80 years of age are rare (Table 3). Ages are read from fin-spine sections but age validation studies have found that the fin ray method consistently underestimates true age (Rien and Beamesderfer 1994; ODFW 2002; Paragamian and Beamesderfer 2003). The accuracy of fin ray ages continues to be debated among scientists throughout the region and may vary among populations depending on growth.

White sturgeon typically grow 6-10 in (15-25 cm) in their first year and 2 to 3 inches per year (5-8 to 15 cm) per year from ages 1 through 20 (Figure 14). Individual growth rates are highly variable and fast growing individuals can be several times larger than slow growing individuals of the same age.

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.

Male and female white sturgeon differ in size-at-age after about 15 to 20 years of age due to sex differences in size and age of maturity. Males are typically smaller because earlier maturation diverts energy from somatic growth into reproduction.

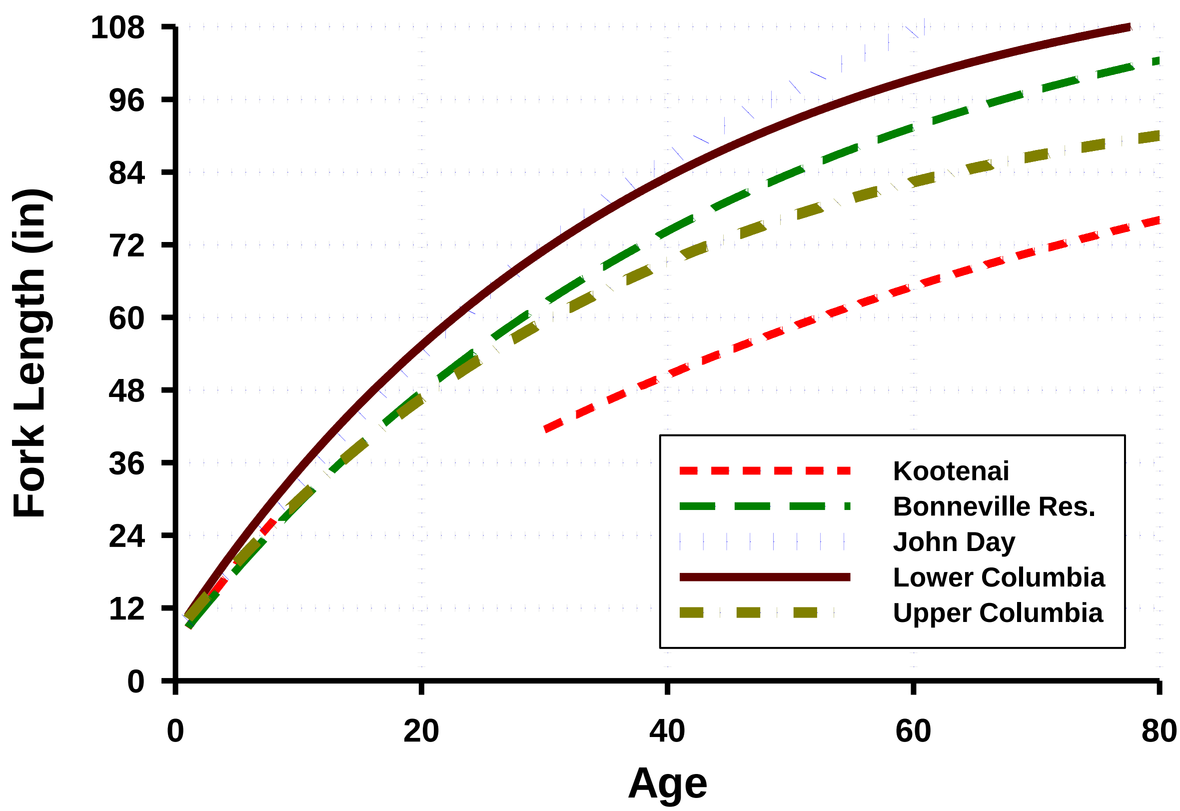


Figure 14. White sturgeon von Bertalanffy growth curves (parameters from Table 3).

2.4.3 Maturation & Fecundity

Compared to other fishes, initial sexual maturity of white sturgeon does not occur until relatively large sizes and advanced ages. Males typically mature at smaller sizes and ages than females (Bajkov 1949; Scott and Crossman 1973; Galbreath 1985; Hanson et al. 1992; Welch and Beamesderfer 1993; IPC 2005). Males may be sexually mature between 100-150 cm FL (39-60 in) and ages 12-25. Females typically mature at 120-180 cm FL (47-71 in) and ages 15-30.

First maturity in white sturgeon is related to both size and age (Conte et al. 1988). Differences in growth rates among subpopulations can result in differences in maturation size. Median sizes of female maturation have been reported to range from 160-194 cm FL (63-76 in) in the lower Columbia River and lower mid-Columbia reservoirs (Figure 15). The smallest mature females were observed in the Bonneville Reservoir where growth was relatively slow. Median size of female maturation was even smaller in the slow-growing Kootenai River population (140 cm or 55 in: Paragamian et al. 2005). Sizes of maturation in the upper Columbia River were similar to those reported by Welch and Beamesderfer (1993) for lower Columbia River populations (RL&L 1996).

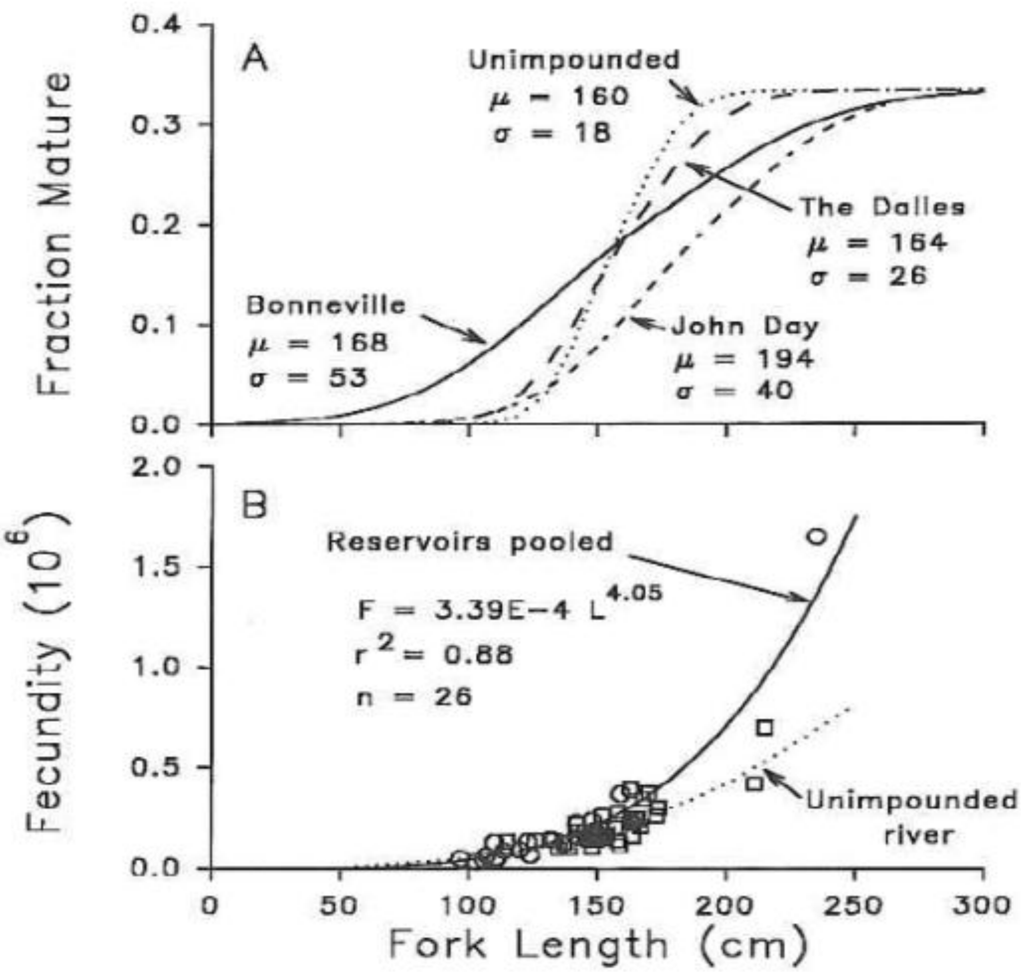


Figure 15. (A) Maturity and (B) fecundity (millions of eggs) versus size of female white sturgeon in three reservoirs and the unimpounded lower Columbia River (from Beamesderfer et al. 1995).

After reaching maturity, white sturgeon may spawn several times over the course of their life (Scott and Crossman 1973; Bemis and Kynard 1997; Webb and Kappenman 2008). Neither individual male nor female adult white sturgeon spawn annually in the lower Columbia River (Webb and Kappenman 2008), although males in captivity are capable of spawning annually (M. Webb, Montana State University, personal communication).

Reproductive periodicity in the lower Columbia River generally ranges between 3 to 5 years for both male and female white sturgeon (Webb and Kappenman 2008, 2009). Thus, in any given year, only a percentage of the population is estimated to spawn. The multi-year reproductive periodicity is due in part to the metabolic demands of their female cyclical reproductive process (vitellogenesis), which requires 16 months or more to complete under conditions in the wild (Conte et al. 1988, Detlaff et al. 1993, Doroshov et al. 2002). As a result of this protracted maturation cycle, females sampled in any given year may include ripe, developing, and resting gonadal stages (Welch and Beamesderfer 1993). Females may also resorb eggs in some years rather than spawning although this follicular atresia is relatively rare in the wild (van Damme et al. 2009).

Female white sturgeon are very fecund, particularly at large sizes. Fecundity of lower Columbia white sturgeon was reported to range from 32,000 to 1.65 million with numbers increasing exponentially with fish size (North et al. 1993). North et al. (1993) also reported that egg diameter increased with increasing fish size.

2.4.4 Recruitment

Recruitment refers to the successful production of an annual year class from spawning through early life history to age 0 or 1. Annual recruitment is highly variable among subpopulations and from year-to-year within many subpopulations. Spawning is believed to occur annually in all areas containing adult sturgeon but recruitment appears to be regulated at one or more points before fish reach one year of age. The scale and frequency of recruitment is the primary factor determining the status of subpopulations throughout the basin.

Under natural conditions, a viable sturgeon population might theoretically be sustained by periodic large year classes sufficient to bridge extended periods of unfavorable conditions. The life history strategy involving episodic recruitment is consistent with the longevity, delayed maturation, large fecundity, inter-generational spawning, and iteroparous characteristics of all sturgeons. However, the more abundant populations in the region are associated with a pattern of consistent annual recruitment. For instance, successful annual recruitment has been observed in the lower Columbia River every year that it has been assessed (McCabe and Tracy 1994; Chapman and Weaver 2006). Many impounded populations are characterized by periodic recruitment events which produce strong year classes and cyclical population patterns. Remnant populations consisting of large, old fish are typical of areas where recruitment has failed. For instance, no strong year class of Kootenai sturgeon has been naturally produced since at least 1974 and possibly not since prior to 1960 (Paragamian et al. 2005; Rust and Wakkinen 2011).

Although factors controlling year class strength are poorly understood, recruitment has been positively correlated with flow volume in many sturgeon species, including white sturgeon

(Votinov and Kasyanov 1978; Kohlhorst et al. 1991; Anders and Beckman 1993). In the lower Columbia River, high spring 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. Positive effects of increased flows on natural production 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.

2.4.5 Survival/Mortality

The longevity of sturgeon is clearly associated with low natural mortality rates beyond the first few years of age. Annual survival rates for long-lived fish like white sturgeon are typically 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. 1995). Annual mortality estimates for Columbia basin white sturgeon are summarized in Table 4. Because sturgeon are so long-lived, population trends are extremely sensitive to small changes in survival rates of only a few percent. Most methods of estimating survival are not accurate enough to discern differences this small.

Table 4. Mortality estimates reported for Columbia and Snake river white sturgeon.

Location	Stage	Includes	Value	Method	Source
L. Col. River	94-175 cm FL	Natural	0.09	Catch curve	DeVore et al. 1995
	Ages 10+	Natural	0.07	Pauly method	Beamesderfer et al. 1995
L. Col. reservoirs	Ages 1-10	Natural	0.21	"	"
	Ages 10+	Natural	0.04-0.05	"	"
U. Snake – Bliss reach	Adults	Total	0.06	Catch curve	Cochnauer 1983
U. Snake – Bliss reach	Adults	Total	0.16	Catch curve	Lepla & Chandler 1998
U. Col. transboundary	Adults		0.03	Mark-recap	UCWSRI 2013
Kootenai	Adults	Total	0.09	Mark-recap	Paragamian et al. 2005
Kootenai	Adults	Total	0.06	Mark-recap	Beamesderfer et al. 2012

2.5 GENETIC STOCK STRUCTURE

Analysis and understanding of white sturgeon genetics is complicated. White sturgeon are polyploid organisms, making them distinct among fishes. Unlike humans who have 46 chromosomes (DeGrouchy 1987) and are diploid, that is an organism that has two sets of identical chromosomes, or Chinook salmon *Oncorhynchus tshawytscha,* which have 68 chromosomes (Simon 1963) and are tetraploid (Allendorf and Thorgaard 1984), that is organisms with four sets of identical chromosomes, white sturgeon possess ~250 chromosomes and are believed to be octoploid, that is, an organism with eight complete sets of identical chromosomes (Birstein 2005; Vasil'ev 2009; Drauch Schreier et al. *in press).* This octoploid appears to be variable in white sturgeon as a function of variability associated with their modes of inheritance (A. Drauch Shreier, University of California, Davis, personal communication). Rodzen and May (2002) noted that ploidy levels in white sturgeon may range from two copies of a chromosome (disomy), to at least eight copies of a chromosome (octosomy).

A series of early genetic studies using various indicators has provided a general picture of current population genetic patterns among populations of white sturgeon throughout the western U.S. and throughout the Columbia River system. White sturgeon genetic studies began with allozymes in the 1980s followed by a series of mitochondrial (mtDNA) studies from the mid-1980s until the early 2000s. More recent genetic analyses are focused on developing and applying microsatellite (μSat) methods that hold greater potential for clarifying genetic population structure and providing new insights into important current and historical patterns.

Statistically 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. 1992, Nelson et al. 1999, McKay et al. 2002, Anders and Powell 2002). Haplotype and nucleotide diversity was slightly greater in the Fraser than the Columbia (Brown et al. 1992; Nelson et al. 1999; McKay et al. 2002; Anders and Powell 2002). Brown et al. (1990) observed four unique haplotypes in the Fraser and two in the Columbia. McKay et al. (2002) observed five unique types in the Fraser, two in the Nechako, and seven in the Columbia. Anders and Powell (2002) also observed five unique haplotypes in the lower Fraser River, two in the Nechako River, and another eight types in the Columbia but not the Fraser. Anders and Powell (2003) found that all Sacramento haplotypes were represented in the Columbia but not vice versa. Four of eight Sacramento haplotypes were not represented in the Fraser River.

Brown et al. (1992) 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) noted that this pattern may have also followed historical regional panmixia during recent period of glacial refugia, and that latitudal clinal variation appears to occur less distinctly in white sturgeon than in other North American sturgeons. Expansive haplotype distribution indicated little mitochondrial 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 (Anders et al. 2002; McKay et al. 2002). This conclusion is consistent with observed recaptures of small numbers of tagged Columbia River white sturgeon in the Sacramento and Fraser Rivers (DeVore et al. 1999).

Genetic studies have determined that white sturgeon subpopulations throughout the Columbia River basin are closely related. Genetic diversity graduates clinally from the river mouth to headwaters such that distinct genetic units cannot be cleanly delineated. Genetic studies have consistently documented decreasing diversity with distance upstream (Bartley et al. 1985, Brannon et al. 1987, Brown et al. 1992, 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). All genetic types found in the upper basin were also found in the lower basin. However, many types found in the lower basin did not occur upstream. Genetic characteristics of populations in adjacent subpopulations separated by dams are generally identical or very similar. Similar patterns of lower diversity of inland samples have also been reported in the Fraser system (Brown et al. 1992, Nelson et al. 1999, McKay et al. 2002, Anders and Powell 2002).

The exception is for the Kootenai population which has been isolated above the impassable Bonnington Falls in the lower Kootenai River since the last ice age approximately 10,000 years ago. Genetic differences were pronounced in the Kootenai River white sturgeon population where heterozygosity was the lowest of observed population (Bartley et al. 1985; Brannon et al. 1987; Setter and Brannon 1990, 1992; Anders and Powell 2002). Significant genetic differences of the Kootenai population also reflect differences in other characteristics. For instance, Kootenai River white sturgeon spawn at consistently lower temperatures and water velocities than other white sturgeon populations.

More recent nuclear microsatellite analyses found similar population structure and genetic diversity patterns as those reported from the allozyme and mtDNA analyses described above. Rodzen et al. (2004) provided the first microsatellite screen including a total of 9 white sturgeon populations from the Columbia, Fraser, and Sacramento rivers, with samples of 38 to over 100 fish per population. Populations associated with unimpounded lower river systems, near the Pacific Ocean, and not just those with the highest samples sizes, had the highest diversity (number of μSat alleles; Figure 16). For example, the Lower Fraser River had 47 samples and 129 alleles, Columbia River estuary had 38 samples and 125 alleles, and the Sacramento River had 38 samples representing 118 alleles. Alternatively, Kootenai/y samples had the lowest number of observed alleles; even when Kootenai/y sample sizes ranged from 49 to 79 fish, only 35 to 37 were present. When standardized for the number of μSat alleles per locus, white sturgeon populations in the lower Columbia River, the Columbia River estuary, and the Sacramento River averaged 2.5-3.5 alleles per locus, compared to 1.5-2.0 for McNary, Lake Roosevelt, and Nechako river (Upper Fraser tributary in BC) populations, and < 1 allele per locus for an upper Snake River and Kootenai River populations (Figure 17).

Microsatellite marker suites, analyses, and sample collections have been improved considerably since initial analyses. Further genetic analysis with the most comprehensive suite of μSat markers is ongoing at the University of California Davis' Genomic Variation Lab and at the CRITFC Hagerman Genetics Laboratory. This ongoing work is expected to provide additional insight into future designs and program development for white sturgeon aquaculture programs in the Columbia basin.

The weak genetic differentiation among sturgeon samples from the lower, middle, and upper Columbia River is consistent with and could be explained by the lack of historically significant migration barriers to sturgeon in the Columbia River between the ocean and Canada, during pre-dam conditions over the past 10,000 years and the wide-ranging life history pattern of this species. The historical genetic population structure was shaped by post-glacial recolonization from common refugia. Glaciers covered much of the upper basin but the lower Columbia is believed to have provided a refuge for freshwater fishes. White sturgeon historically had free range to move throughout the system. Higher diversity in the lower basin might also suggest that anadromous behavioral patterns may be less prevalent among fish in the upper portions of basins.

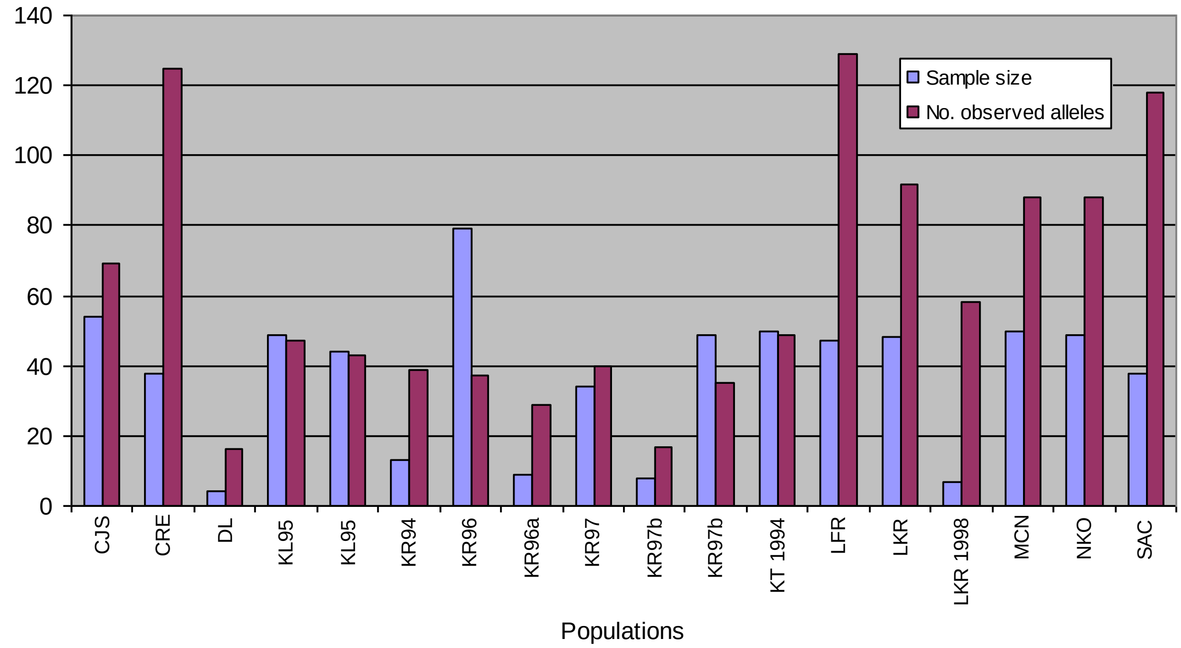


Figure 16. Sample size and number of observed alleles from 18 population or sample groups of white sturgeon (From Rodzen et al. 2004). Population codes: KL=Kootenay Lake, KR=Kootenai River, KT=Kootenai River, CJS=C. J. Strike Reservoir, CRE=Columbia River estuary, LFR=Lower Fraser River, MCN=McNary Pool, NKO=Nechako River, SAC=Sacramento River.

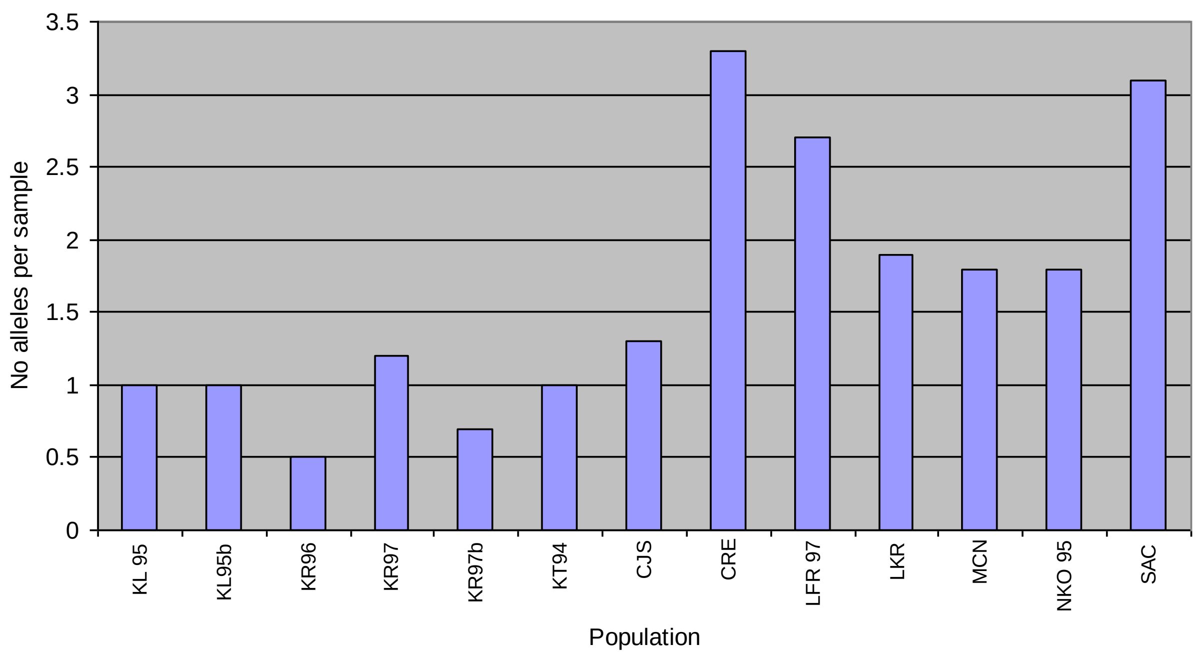


Figure 17. Number of alleles per sample by population or sample group where n>10, comparing genetic variability among Kootenai River, Kootenay Lake, and other white sturgeon populations from throughout the species range. Population codes: KL=Kootenay Lake, KR=Kootenai River, KT=Kootenai River, CJS=C. J. Strike Reservoir, CRE=Columbia River estuary, LFR=Lower Fraser River, MCN=McNary Pool, NKO=Nechako River, SAC=Sacramento River.

It remains unclear how much of current patterns reflect historical conditions and how much is an artifact of human disturbance over the last 150 years. Current population segments may not represent a historical. Overfishing during the late 1800s substantially reduced effective population sizes. Dam construction since the 1930s has fragmented the population and replaced bi-directional gene flow, which provided a natural source of genetic variation, with predominately downstream gene flow. Current movements are primarily downstream in nature through entrainment (Coutant and Whitney 2000; Parsley et al. 2007) and other passage routes including spill ways, fish ladders, and navigation locks (Parsley et al. 2007). Upstream movements, though possible at some dams, are uncommon throughout the FCRPS (North et al. 1993; Parsley et al. 2007). Genetic diversity of impounded populations is threatened by small effective population sizes due to low abundance, the periodic sturgeon maturation cycle, and environmental patterns that present only opportunities for successful reproduction.

Genetics are an important consideration in defining appropriate sturgeon management units to address specific sturgeon issues in different portions of the basin. Genetic population structure can also have important management implications, particularly for hatchery activities (e.g. broodstock selection, effective population sizes and mating protocols). In a facilitated work session, participants were asked to delineate genetic management units for white sturgeon in the Columbia River basin based on their expert opinion and the available information on genetic population structure (Beamesderfer et al. 2011). Genetic management units were generally defined as areas of similar genetic characteristics that may warrant some consideration in implementation of sturgeon conservation and management measures. The workshop highlighted the difficulty of attempting to delineate distinct units where the genetic diversity graduates clinally from the river mouth to headwaters. Figure 18 identifies five genetic management units consistent with recommendations of the workshop participants. Boundaries of the mid-Columbia unit were drawn overlapping adjacent units to reflect the observed gradation in genetic characteristics from area to area.

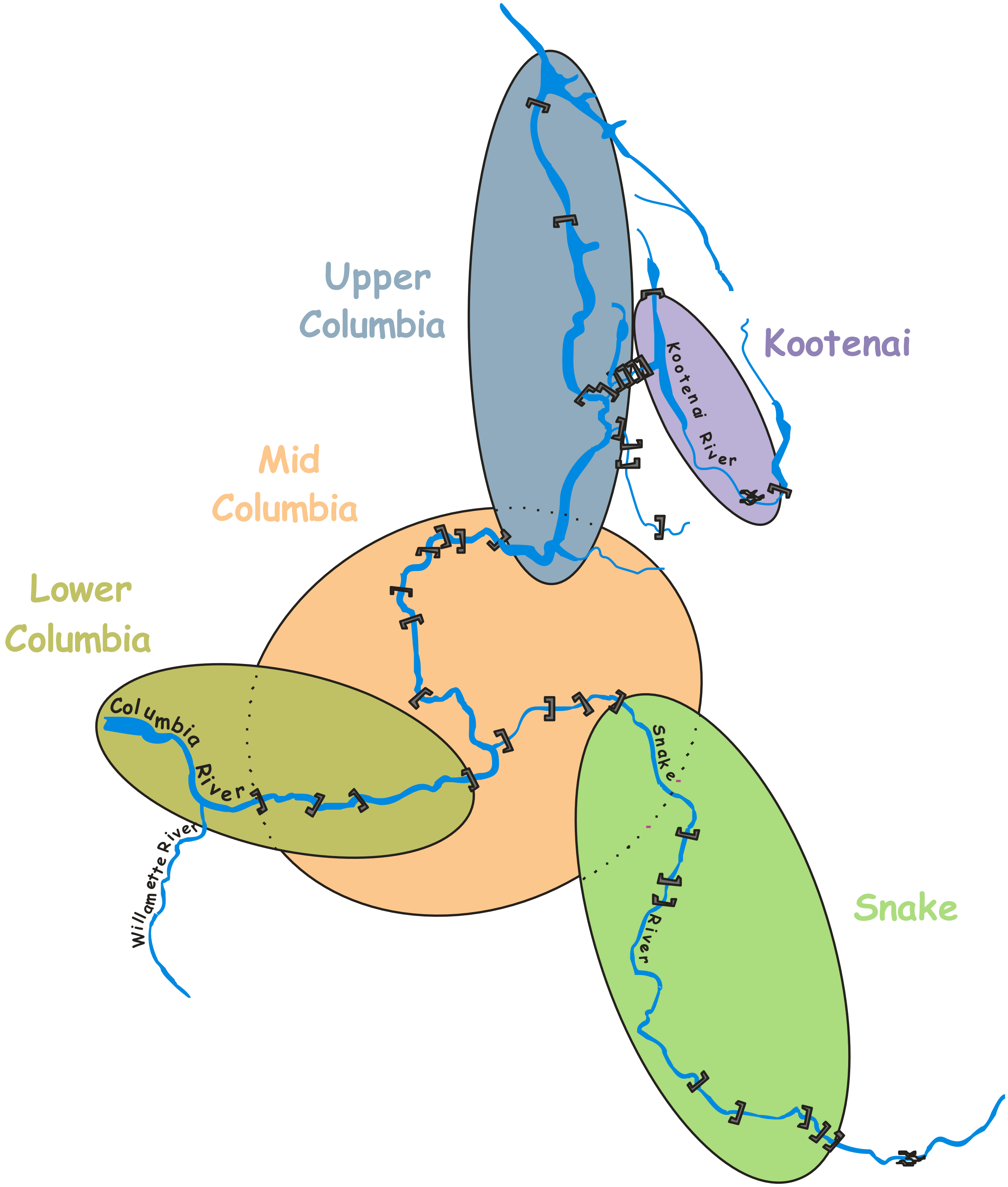


Figure 18. Columbia Basin Sturgeon Genetic Management Units.

3 CURRENT STATUS

White sturgeon distribution, abundance and diversity have declined substantially throughout the Columbia basin but significant naturally self-sustaining subpopulations continue to be found in portions of their historical range. Numbers and distribution are continuing a long term decline in many areas as natural production is no adequate to replace remnant populations.

3.1 DISTRIBUTION AND SPATIAL STRUCTURE

In the Columbia River basin, white sturgeon historically had access from the ocean to Windermere Lake in the upper Columbia River and to Shoshone Falls in the upper Snake River. A Kootenai River population has been isolated from downstream populations and from upstream gene flow by Bonnington Falls (downstream from Nelson B.C.) since the last active glacial period, approximately 10,000 years ago (Northcote 1973). The Kootenai population utilizes Kootenay Lake and the river as far upstream as Kootenai Falls in Montana. White sturgeon inhabited the Willamette River upstream to Willamette Falls and might conceivably ranged upstream from the falls during floods. In more recent years, juvenile sturgeon have been transplanted upstream from Willamette Falls by the Oregon Department of Fish and Wildlife. White sturgeon also periodically used portions of larger tributaries. These included the Cowlitz, Clearwater, Salmon, Spokane, Pend d'Oreille, and Kootenay rivers as well as smaller tributaries such as the Sanpoil, Kettle, Slocan, and Salmo rivers.

Prior to extensive hydrosystem development, subpopulations with access to the ocean may have included a mixture of anadromous and resident life histories, with the incidence of anadromy presumably decreasing in the upper river reaches. Subpopulations in the upper reaches of the basin may have expressed resident life history traits and likely benefited from the availability of anadromous salmon, both as a high calorie food item and as a source of marine derived nutrients that enrich naturally oligotrophic inland waters (Cederholm et al. 1999; Schindler et al. 2003, Stockner 2003; Stockner and Ashley 2003).

The population now consists of several known or suspected subpopulations that are effectively isolated from each other. What may have once been a single white sturgeon population, or a series or broadly overlapping meta-populations, has now been restricted and fragmented by dam. 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. Status varies among impounded subpopulations from marginally productive to functionally extirpated (Figure 19). Most impounded subpopulations remain unable to support significant fisheries anywhere near the scale of that seen downstream from Bonneville Dam, or at historic levels in the same locations. Natural recruitment has failed in most upper Columbia and Snake river subpopulations, which now consist solely of aging cohorts of mature fish that are gradually declining as fish die and are not replaced.

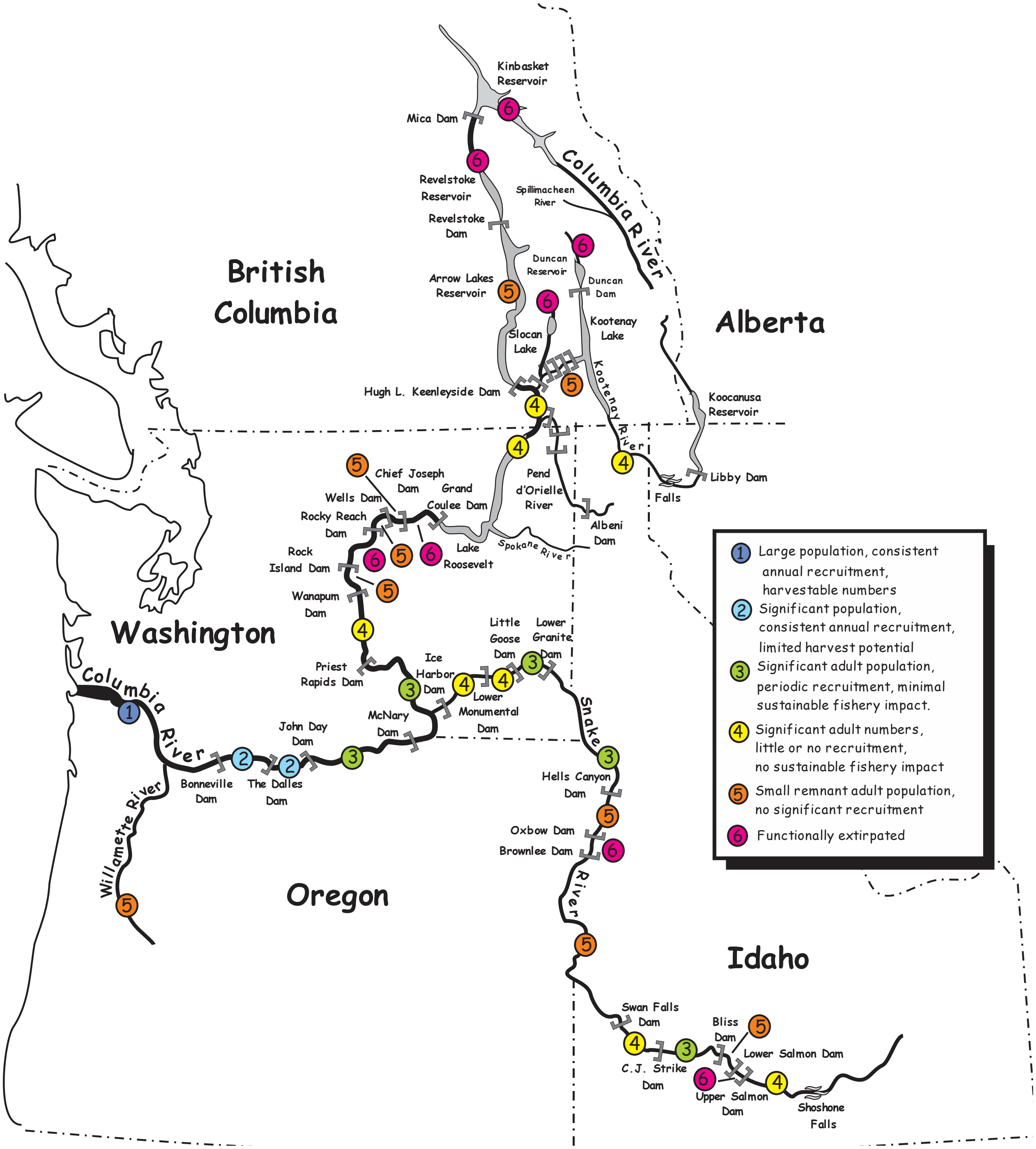


Figure 19. Distribution and status of Columbia and Snake river subpopulations.

3.2 ABUNDANCE

Exact historical numbers white sturgeon in the lower Columbia River are unknown, but the species was reportedly "extremely abundant" (Craig and Hacker 1940). Before a commercial fishery market developed in the 1880s, sturgeon caught in salmon nets were regarded as a nuisance and regularly clubbed and discarded. Commercial harvest around 1890 provide some sense of the large number and biomass of white sturgeon inhabiting the lower Columbia River at that time. In just seven years from 1889-1895, the fishery removed over 180,000 sturgeon weighting over 18 million pounds (approximately 90 lbs per fish) from the area between the mouth and the Snake River. The fishery rapidly mined the sanding stock and collapsed by the late 1890s. However, the harvest numbers represent a minimum estimate of the adult sturgeon population at that time.

Based on fishery harvests and catch rates, the lower Columbia population remained at relatively low levels until the 1960s. Recovery followed the adoption in 1950 of fishery size regulations that allowed harvest only of fish between 30 and 72 inches total length. The regulation was changed to 36-72" TL in 1958 and this regulation remained unchanged until 1989 when the minimum size was increased in response to increasing fishing pressure. The maximum size limit protected the population of mature spawning adults and this protection was believed to be responsible for subsequent population growth.

By 1990, DeVore et al. (1995) estimated that the lower Columbia supported a population of about 1 million sturgeon 54 cm FL (21 in) and larger. The current lower Columbia River white sturgeon population remains the largest in the Columbia Basin, and of the species on the west coast as a whole (Smith 1990; DeVore et al. 1995). Numbers appeared to peak during the 1990s and have subsequently declined by approximately half (ODFW and WDFW 2013). Jones (2011) estimated abundance at 665,000 for fish at least ≥ 53 cm FL. These estimates do not include that portion of the population downstream of Bonneville Dam but outside the mainstem lower Columbia River (e.g., coastal estuaries and near-shore marine environments). This decline has been related to decreasing annual recruitment and may also be influenced by increased mortality due to growing predation by sea lions.

Abundance of sturgeon upstream from Bonneville Dam is much less than in the lower river. Numbers vary considerably from subpopulation to subpopulation but generally increase with increasing distance upstream (Table 5). Populations number in the tens or hundreds of thousands may be found in the three lowermost reservoirs (Bonneville, The Dalles, John Day). Significant juvenile recruitment in these areas is such that populations continue to support modest levels of fishery harvest. In order to ensure sustainable fisheries and optimize harvest in this area, population assessments are completed in each of these three reservoirs on a three-year rotating cycle.

The upper mid-Columbia and lower Snake reservoirs generally contain only small remnant populations supported by little or no annual recruitment. Populations may range from a few dozen up to several hundred or thousand fish. These populations are generally dominated by larger, older fish. Overall, abundance in these populations is declining or possibly stable at a low level. Population assessments in these areas are expected to occur at periodic intervals in the future in association with monitoring of mitigation actions.

Significant numbers of sturgeon still occur in the upper Columbia but recruitment has largely failed and the wild population is now dominated by a declining number of large, old fish. Approximately 3,000 wild sturgeon are estimated to inhabit the transboundary reach from Lake Roosevelt to the H. L. Keenleyside Dam (Howell & McLellan 2007; Golder 2005). Only a few dozen fish are estimated to remain in Arrow Lakes upstream from Keenleyside Dam and only a handful of individuals are through to occur in other areas upstream from Revelstoke Dam (Hildebrand and Parsley 2013). The Upper Columbia population of white sturgeon in Canada was listed as endangered under the Canadian Species at Risk act in 2006. A conservation aquaculture program was initiated in 2001 to supplement existing wild populations. Juvenile hatchery-reared white sturgeon have been release annually in the Keenleyside reach since 2002 (n = 93,524), into the Roosevelt reach since 2004 (n=29,031), and into Arrow Lakes since 2007 (n = 36,643). Significant survival and growth of these hatchery fish has been documented.

The Kootenai population inhabiting Kootenay Lake and the Kootenai River upstream to Kootenai Falls is the only white sturgeon listed under the U. S. Endangered Species Act (listed as Endangered in 1994). This population is estimated to have been declining for several decades as natural recruitment has failed and the remaining adults gradually die off. Approximately 1,000 wild sturgeon were estimated to remain in 2009 (Beamesderfer et al. 2013). The Kootenai population was recently estimated to be larger than previously reported by Paragamian et al. (2005) due to previously unaccounted for fish in the Kootenay Lake. However, this wild population continues to dwindle. Conservation hatchery programs have been developed in the Kootenai river in an attempt to forestall extinction. An estimated 15,994 juvenile hatchery-produced sturgeon were present in the Kootenai population in 2012 from releases of 200,274 fish between 1992 and 2011 (Beamesderfer and Garrison 2013).

White sturgeon are found in varying numbers throughout the middle and upper Snake Rivers. Dams in the Snake River hydroelectric complex separate the fish into twelve subpopulations. Only two of the reaches, Bliss Dam to C.J. Strike Reservoir and Hells Canyon Dam to Lower Granite Reservoir, currently support viable populations, characterized by self-sustaining natural recruitment. Assessments indicate that the other reaches support small populations with little or no detectable reproduction.

Table 5. **Estimated abundance of white sturgeon by management unit.**

Area	Subpopulation	Number	Includes	Reference
L. Columbia	Mouth - Bv Dam	**1,010,000**	> 20 in. FL (2010)	Jones 2011
L. Mid-Columbia		**512,532**		
	Bonneville	333,423	> 20 in. FL (2009)	
	The Dalles	133,260	> 20 in. FL (2008)	
	John Day	40,649	> 20 in. FL (2010)	
	McNary	5,200	> 28 in. FL (1995)	
U. Mid-Columbia		**756**		
	Priest Rapids	134	> 28 in. FL (2002)	
	Wanapum	551	> 28 in. FL (2002)	
	Rock Island	4	1 pass; 4 fish (1998)	
	Rocky Reach	29	> 28 in. FL (2001)	
	Wells	31	> 28 in. FL (2007)	
	Lake Rufus Woods	7	1 pass; 7 fish (1998)	
U. Columbia		**3,188**		
	Roosevelt Reach	2,037	> 28 in. FL (2005)	Howell & McLellan 2007
	Keenleyside Reach	1,151	> 13 in. FL (2004)	Golder 2005
Far U. Columbia				
	Arrow Lakes	**52**	Adults (2003)	Golder 2006
Kootenai		**16,985**		
	Kootenai (wild)	991	47-102 in. FL (2007)	Beamesderfer et al. 2013
	Kootenai (hatchery)	15,994	< 42 in FL (2012)	Beamesder & Garrison 2013
Lower Snake		**15,580**		
	Ice Harbor	4,830	>20 in. FL (1996)	
	Lower Monumental	4,260	>20 in. FL (1997)	
	Little Goose	6,490	>20 in. FL (1997)	
Middle Snake		**3,625**		
	Lower Granite – Salmon R	2,313	(1997-00)	Lepla 2003
	Salmon R – Hells Canyon	1,600	(1997-00)	Lepla 2003
	Lower Granite – Hells Cyn.	3,625	(1997-00)	Lepla 2003
Upper Snake		**6,898**		
	Hells Canyon - Oxbow	--	(1998)	Lepla 2003
	Oxbow - Brownlee	--	(1998)	Lepla 2003
	Walters Ferry - Swan Falls	155	> 28 in. (1996-97)	Lepla 2003
	Swan Falls – C. J. Strike	726	> 35 in FL (1994-96)	Lepla & Chandler 1997
	C.J. Strike - Bliss	2,554	> 31 in. (1991-93)	Lepla & Chandler 1998
		3.013	> 28 cm (2007)	IDFG 2008
	Bliss - L. Salmon Falls	83	> 28 in. (2004)	IDFG 2008
	L. to U. Salmon Falls Dams	21	> 28 in. (2009)	IDFG 2008
-	U. Salm. Falls – Shoshone Falls	346	> 28 in. (2008)	IDFG 2008

3.3 PRODUCTIVITY

The white sturgeon population in the Columbia River downstream from Bonneville Dam is among the most productive sturgeon populations in North America. Abundance and biomass have been estimated at 36.1 fish/acre and 88 lbs/acre, respectively (DeVore et al. 1995). Current white sturgeon biomass in the unimpounded lower mainstem appears to be less than levels seen during pristine conditions before significant exploitation in the late 1800s (Jones et al. 2011). White sturgeon downstream from Bonneville Dam continue to range freely throughout lower river mainstem, estuary, and marine habitats to take advantage of dynamic seasonal patterns of food availability. Individual growth, condition, and maturation values from the lower Columbia River remain among the highest observed for white sturgeon range-wide.

Productivity of the impounded white sturgeon population segments upstream from Bonneville Dam is considerably less than that of the lower population in the free-flowing river between Bonneville Dam and the ocean. Reduced productivity in the impoundments likely results from sporadic conditions for recruitment, as well as reduced access to diverse anadromous, estuarine, and ocean food resources. White sturgeon productivity between Bonneville and McNary Dams (measured in harvestable lb/acre/year) has been estimated at only 15 percent of the unimpounded population downstream from Bonneville Dam (Beamesderfer et al. 1995). In general, impounded white sturgeon populations grow slower and mature later, and maintain lower condition factors than the unimpounded population. Productivity of sturgeon populations in the Columbia and Snake rivers upstream from John Day Dam is very low.

4 OVERVIEW OF FISHERIES

4.1 HISTORY OF WHITE STURGEON FISHERIES

Commercial use of white sturgeon in the Columbia River has been documented since the middle of the 19th century, with the first reported commercial sales being to European explorers by Native American tribes along the Columbia River (Craig and Hacker 1940). Between 1870 and 1890, settlers in the area developed commercial gillnet, trap, and fish wheel fisheries for salmon species. White sturgeon captured in these fisheries were considered safety hazards; those caught, regardless of size, were commonly destroyed and discarded (Craig and Hacker 1940; Hanson et al. 1992). The first verified record of white sturgeon sales occurred in 1884 (Hanson et al. 1992). Four years later a fully developed directed fishery was established in the lower Columbia River, second in value only to the salmon fishery (Craig and Hacker 1940). The directed white sturgeon commercial fishery peaked in 1892, with a harvest of nearly 5.5 million pounds (2.5 million kg) in the absence of any harvest regulations. Sturgeon abundance dropped dramatically between 1893 and 1895 (Craig and Hacker 1940).

Sturgeon fishery management actions were initiated in 1899 with the adoption of a 4-ft (122 cm) TL minimum size limit and a 4-month fishing season; "Chinese sturgeon lines" (setlines using numerous un-baited hooks to snag fish as they swim by) were banned for commercially-landed sturgeon. Despite, and perhaps partly because of, these regulatory changes the fishery collapsed and less than 75,000 pounds (34,000 kg) were harvested in 1899 (Craig and Hacker 1940). From 1899 to 1908, commercial sale of sturgeon was prohibited. Beginning in 1909, commercial sales were allowed during salmon seasons only. The white sturgeon commercial fishery remained functionally non-existent and only incidental to salmon fisheries for the next 70 years (Craig and Hacker 1940; Hanson et al. 1992; ODFW/WDFW 2009). An annual targeted white surgeon commercial fishery was not reinstated until 1974 when the stock partially recovered.

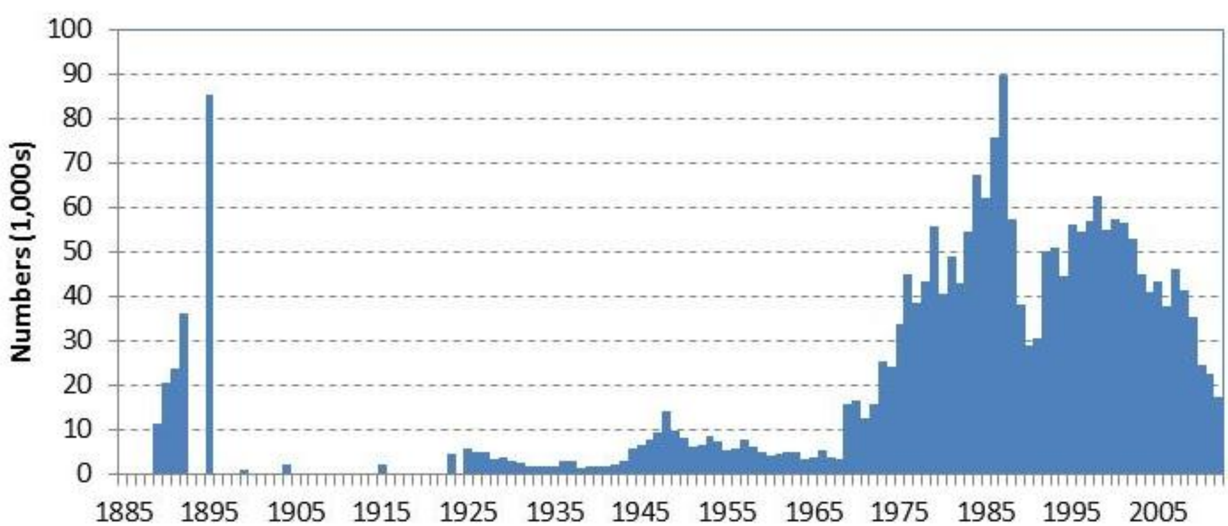


Figure 20. Historical harvest of white sturgeon in lower Columbia River fisheries.

Columbia River below Bonneville Dam

Sturgeon management expanded to encompass recreational fisheries beginning in 1940. Between 1940 and 1989, fishery management actions primarily consisted of modifying catch limits for the recreational fishery and legal size restrictions for both recreational and commercial fisheries. Most notable was the adoption of a 6-ft (182 cm) TL maximum harvestable size regulation for sport and commercial fisheries in 1950. The purpose of the maximum size limit restriction was to protect broodstock and aid recovery of the Columbia River population. This management action was likely the catalyst for rebuilding white sturgeon stocks in the Columbia River. Additionally, commercial sturgeon setline seasons in place during 1975-1983 were discontinued. By 1985, large mesh (≥ 23 cm; 9 inches) gill nets were established as the primary gear for white sturgeon (Galbreath 1985; Hanson et al. 1992).

Prior to 1970, recreational angling for white sturgeon was limited, and focused primarily in the area 15 miles immediately downstream of Bonneville Dam. Further, the fishery lacked any kind of regulation prior to 1940 (Hanson et al. 1992). In 1974, lower Columbia River sport salmon fisheries were severely restricted to protect upriver salmon and steelhead runs. The white sturgeon population appeared to be healthy and increasing in abundance at this time. Anglers and resource managers responded and white sturgeon angler trips and catches more than doubled by 1980 (Hanson et al. 1992). Sport catches and effort generally increased through the 1980's, and peaked in 1987, with more than 175,000 angling trips and 62,000 white sturgeon harvested in the lower Columbia River (Hanson et al. 1992; ODFW/WDFW 2007).

In 1988, managers and researchers began to examine combined commercial and sport exploitation rates. Landings from combined fisheries were estimated at more than twice what was believed to be sustainable (Rieman and Beamesderfer 1990; Hanson et al. 1992). Subsequent harvest restrictions and intensively managed fisheries have been implemented as a result (Table 2; ODFW/WDFW 2007).

In October 1996, a management agreement referred to as the Oregon and Washington Joint State Accord (Accord) was formally adopted by the states of Oregon and Washington. The cornerstone of the Accord is the implementation of three-year average harvestable guidelines that are based on the most recent abundance information. These guidelines are intended to ensure that cumulative fishery impacts do not exceed sustainable levels, as determined by short-term trend indices.

The number of anglers participating in the lower Columbia River catch-and-release fishery targeting adult fish (i.e., fish that exceed the legal retention size) has declined from its peak in 1995 (Chapman and Weaver 2006; ODFW, unpublished data). However, it remains a popular fishery with an average of 8,200 angler trips occurring in the 17 river miles immediately downstream of Bonneville Dam between 2006 and 2008 (ODFW, unpublished data). Since 2010, all sturgeon angling has been prohibited from May through August in the reach from Bonneville Dam to marker 82 (approximately nine miles downstream) to protect adult fish.

Lower river fisheries outside of the mainstem Columbia River are low relative to in-river catches. Harvest in recreational fisheries in the Willamette River above Willamette Falls, coastal tributaries, and in the ocean average 3 percent of the combined lower Columbia River guideline; the ocean commercial yield for Oregon fisheries averages less than 55 lb per year since 2000.

Due to the recent declining trend in legal abundance estimates, both Oregon and Washington commissions have expressed concern regarding the health of the white sturgeon population in the lower Columbia River. In January 2012, both commissions agreed to reduce the annual allowable harvest rate of white sturgeon from the pre-2012 level of 22.5% to no more than 16% for 2012 and beyond.

In November 2012, the workgroup tasked with restructuring salmon and sturgeon fisheries in the lower Columbia River recommended that white sturgeon retention be discontinued in response to confirmation that the decline in the abundance of legal-sized sturgeon forecast for 2012 indeed occurred. Consistent with that advice, the Oregon commission adopted guidance in December 2012 prohibiting retention of white sturgeon in all fisheries that impact the lower Columbia River population, but elected to postpone implementation until January 2014. The Washington commission did not prohibit retention of sturgeon in 2013. In the interim, the Commissions charged the agency Directors with negotiating an agreement setting white sturgeon harvest levels for 2013 recreational and non-Indian commercial fisheries downstream of Bonneville Dam that incorporates a conservation buffer, reducing the harvest rate by 10% (OFWC guidance) to 25% (WFWC guidance).

Recreational and non-Indian commercial fisheries for white sturgeon in the Columbia River and tributaries downstream of Bonneville Dam will be addressed at the January 30, 2013 Compact/Joint State hearing pending results from the negotiations.

The Joint Staff are scheduled to meet with the CRCAG and the CRRAG on January 23 to brief them on Commission guidance regarding white sturgeon management and results of the negotiations between the two agencies in establishing harvest guidelines for 2013.

Bonneville Dam to McNary Dam (Zone 6)

In 1987, the Sturgeon Management Task Force (SMTF) was formed in response to concerns over increasing catch rates (non-Indian recreational and treaty Indian commercial and subsistence) and declining white sturgeon abundance in the Zone 6 area. The SMTF consists of representatives from Oregon, Washington, and the Columbia River treaty Indian tribes (Nez Perce, Umatilla, Warm Springs, and Yakama). The purpose of the SMTF is to review the status of sturgeon and provide harvest management recommendations for fisheries occurring in the Zone 6 management area. Treaty sturgeon fisheries do not currently occur upstream of McNary Dam, so this area is not considered in SMTF harvest sharing agreements.

Upper Mid-Columbia

Fisheries in all upper Mid-Columbia River reservoirs above Priest Rapids Dam are closed to the retention of sturgeon due to low legal-size adult abundance and/or poor juvenile recruitment from natural spawning.

McNary Dam to Priest Rapids Dam and the lower Snake River

Retention of white sturgeon is allowed in recreational fisheries from McNary Dam upstream to Priest Rapids Dam and in the lower Snake River upstream to Lower Granite Dam during February through July. A 48-inch minimum size limit restriction was implemented in 1991 to manage harvest of fish in these populations.

Upper Columbia

Angling for sturgeon on the upper Columbia became popular in the mid-1970s and this popularity increased steadily to the 1990s. Sturgeon were one of the species targeted by guiding outfits on the upper Columbia River in the late 1980s on the Columbia River. 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 (UCWS.

Idaho

Sport and commercial sturgeon fishing was unregulated in Idaho prior to 1943 (Hanson et al. 1992). By the late 1930s, four dams had been built on the Snake River (Swan Falls, Shoshone Falls, Lower Salmon Falls, and Upper Salmon Falls), although they impounded only about 4 percent of the river. Beginning in 1943, fishing regulations were implemented. Increasingly restrictive sport regulations followed until 1970, when a catch-and-release fishery program was adopted for the entire Snake River in Idaho. While little historical information is available for Idaho white sturgeon populations, past harvest and abundance trends are believed to be similar to those in the Columbia River (USEPA 2002). Cochnauer (1983) suggested that the spawning population in the Snake River would gradually decline with exploitation rates of 0.05 to 0.10 for fish 125–183 cm long, assuming estimates of total instantaneous mortality rates of 0.06 to 0.27 from observed data. The Hells Canyon–Lower Granite white sturgeon population probably experienced exploitation rates of 0.30 (for fish 10 to 20 years old) in the mid-1970s (unpublished data collected by Coon et al. 1977 and presented by Lukens 1985).

4.2 CURRENT FISHERY TYPES & AREAS

4.2.1 Non-Indian Recreational

Recreational angling opportunities in the mainstem Lower Columbia River and its tributaries below Bonneville Dam abound. Oregon and Washington sport anglers harvested an average of 26,972 white sturgeon annually from 2002 to 2011, with a range of 11,195 (2011 preliminary estimate) to 41,200 (2001) fish (ODFW and WDFW 2012); however, while the 10-year average is in excess of 25,000, harvest in the past three years (2009-2011) has declined annually and only averaged 16,380. The non-Indian recreational catch from 2002 to 2011 between Bonneville and McNary dams averaged 1,670, with a range of 962 (2006) to 3,097 (2011) (ODFW and WDFW 2012). Contrary to the Columbia River downstream of Bonneville Dam, the impounded

Columbia River has seen an increase in harvest over the last three years, though recreational harvests in this reach are still an order of magnitude less than the corresponding reach downstream of Bonneville Dam. Total non-Indian recreational harvests in the lower Columbia, inclusive of the Willamette River, have averaged 28,642 fish for the same 10-year period (ODFW and WDFW 2011). Recreational retention fishing opportunities occur upstream to Priest Rapids Dam on the Columbia River and upstream to Lower Granite Dam on the Snake River. Catch and release recreational fishing opportunities also occur in the mid-Columbia River and Snake River upstream of Lower Granite Dam.

4.2.2 Non-Indian Commercial

The Lower Columbia River white sturgeon population provides significant commercial harvest opportunities. Since 1997, commercial sturgeon fisheries have been managed to remain within catch guidelines while maximizing economic benefit and achieving conservation objectives for other species. Annual plans for distribution of the commercial harvest allocation are developed with input from the Columbia River Commercial Fisheries Advisory Group (CRCAG), to provide stable commercial fishing opportunities throughout the year while maintaining optimum market value. Weekly landing limits have remained a valuable tool in maintaining consistent commercial fisheries since first adopted in 2002.

Non-treaty commercial fisheries harvested an annual average of 7,300 white sturgeon between 2002 and 2011 from the lower Columbia River below Bonneville Dam, with a range of 3,305 (2011 preliminary estimate) to 9,620 (2002) (ODFW and WDFW 2012). Similar to recreational catches in this reach, the last three years have seen declines in non-Indian commercial harvests, averaging 5,140 between 2009 and 2011.

4.2.3 Treaty Subsistence

Treaty Indian subsistence sturgeon fishing is open year-round, with sanctuary closures around dams and tributaries. Subsistence catch is estimated through a monitoring program conducted by the Yakama Indian Nation. The subsistence fishery catch during the 10-year period 2002–2011 averaged 335 white sturgeon annually, with a range of 161 (2007) to 652 (2011 preliminary estimate). Similar to Zone 6 recreational harvest, subsistence harvests increased each year between 2009 and 2011, and averaged 496 during the period (ODFW and WDFW 2011).

4.2.4 Treaty Commercial

The treaty Indian commercial fishery occurs in Zone 6 between Bonneville and McNary dams. Sturgeon are harvested with setlines and gillnets during summer and winter fisheries. The 10-year average treaty commercial harvest (2002–2011) from combined gillnet and setline fisheries have averaged 1,899, with a range of 860 (2003) to 3,901 (2011) fish between Bonneville and McNary dams (Table 6); average catch in the last three years (2009-2011) has increased annually and averaged 2,848 fish.

Table 6. Recreational, non-Indian Commercial, treaty subsistence, and treaty commercial harvests for the Columbia and lower Snake rivers, 2002–2011.

Year	LCR Sport	Zone 6 Sport	Total Sport	LCR COM	Zone 6 COM	Zone 6 Sub	McNary	Lower Snake River
2002	38,279	2,625	40,904	9,620	1,950	370	378	402
2003	31,932	2,175	34,107	7,947	1,437	325	258	234
2004	28,443	1,611	30,054	7,866	1,748	269	288	186
2005	30,904	1,106	32,010	8,152	1,741	311	185	228
2006	26,394	962	27,356	8,312	860	201	182	154
2007	35,136	1,039	36,175	7,761	1,124	161	236	192
2008	29,496	1,134	30,630	7,859	1,588	226	336	307
2009	23,829	1,000	24,829	7,737	1,618	219	223	373
2010	14,116	1,946	16,062	4,385	3,026	616	122	480
2011	11,195	3,097	14,292	3,387	3,901	652	155	272
2012	7,860	2,585	10,445	1,922	4,546	447		

4.3 Harvest Guidelines, Yield, Exploitation & Effort

4.3.1 Below Bonneville Dam

The lower Columbia River white sturgeon recreational and commercial fisheries downstream of Bonneville Dam are managed jointly by the states of Oregon and Washington. The Columbia River Compact (Compact) has the congressional and statutory authority to set commercial fishing seasons and adopt associated rules. The Compact is a joint Oregon and Washington panel that was established by the states in 1915, and empowered by Congress in 1918 (Woods 2008). It consists of the ODFW and WDFW agency directors or their delegates who act on behalf of the Oregon and Washington fish and wildlife commissions. Recreational fisheries are established during Joint State Hearings by ODFW and WDFW. These hearings are functionally similar to the Compact hearings; however, since the Compact is only empowered to enact commercial fishing actions they are treated as separate events. Functionally, Compact hearings and Joint State Hearings often act on similar issues, and therefore often occur at the same time.

Since 1989, lower Columbia River white sturgeon fisheries have been managed for optimum sustained yield (OSY). This management strategy is intended to optimize harvest while allowing for the continued rebuilding of the white sturgeon population. Significant management actions taken during 1985-1996 to restrict catches to sustainable levels included (1) increasing the minimum size limit in recreational fisheries, (2) reducing the maximum size limit in all fisheries, (3) reducing daily and annual catch limits for recreational fisheries, and (4) adopting annual catch guidelines for commercial fisheries (ODFW and WDFW 2012).

The OSY management strategy is intended to allow for the continued rebuilding of the white sturgeon population while providing harvest opportunities. The Accord contains implementation guidelines for three-year average harvest limits based on the most recent abundance information. The intent of these guidelines is to ensure that cumulative fishery harvests do not exceed sustainable levels. Emergency actions may be taken during the three-year agreement if new information becomes available that indicates substantial changes in stock status. The Accord was re-affirmed in 2000, 2003, and 2006, with adjustments made to the harvest guidelines as needed.

A new three-year Accord was adopted by the Oregon and Washington fish and wildlife commissions in February of 2011 to cover the years 2011-2013. No changes were made to allocations among fisheries or areas, and broodstock sanctuaries remain as adopted in 2010. The harvest originally mandated by the current Accord for 2011–2013 is 17,000 fish or 22.5 percent, whichever was less; however, following the 2011 population estimate the Accord was modified and harvest rate was reduced to the 16 percent rate recommended by the Lower Columbia River and Oregon Coast White Sturgeon Conservation Plan. The harvest guideline is set at 17,000 and has a 2011 projected exploitation rate of 22.5 percent; however, due to the modifications in the Accord, the guideline dropped in 2012. The 2013 guideline will be determined following the 2012 stock assessment.

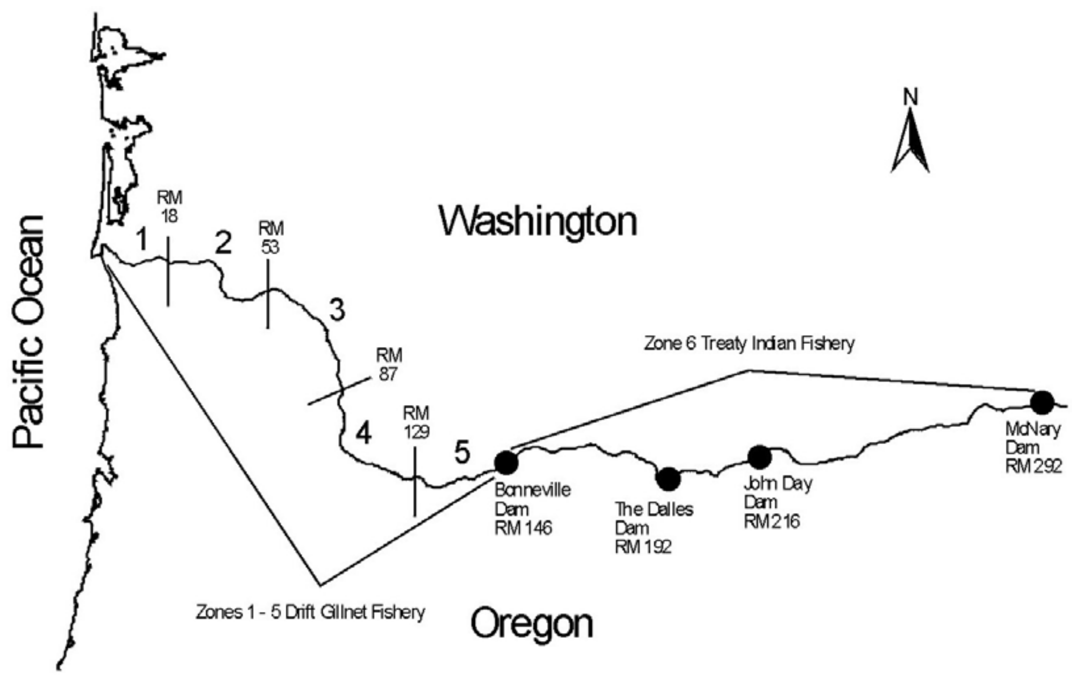


Figure 21. Map showing commercial fishing zones of the Columbia River from the mouth to McNary Dam (ODFW 2011).

Currently, white sturgeon harvest in lower Columbia River commercial fisheries is managed to distribute landings throughout the year in order to maximize economic benefit and help distribute the catch throughout the five commercial fishing zones (Figure 21). Commercial fishing seasons occur during winter (January-mid March), spring (late March-mid June), summer (mid June-July), early fall (August), and late fall (late September-October) timeframes in the mainstem Columbia, and nearly year-round (February-October) in off-channel Select Area fisheries. In cooperation with the Commercial Advisory Group, ODFW and WDFW staff establish season-specific harvest guidelines for each of the commercial fishing seasons. Harvest is then managed within those guidelines with some in-season flexibility. During the winter and late fall seasons, fishing periods designed to target white sturgeon occur. During the remainder of the year, the majority of white sturgeon are harvested incidental to salmon-directed fisheries. For most commercial seasons, weekly (per vessel) landing limits are imposed to ensure harvest are within season-specific guidelines, to distribute catch throughout the fisheries, and to maintain market prices. Although individual fishermen have mixed opinions, the commercial industry as a whole has generally prioritized harvest of white sturgeon during the winter, August, and late fall seasons with the balance of the available harvest distributed throughout the other fishing seasons.

Lower Columbia River white sturgeon recreational fisheries are managed to provide year-long harvest opportunities seven days per week, minimize in-season emergency action, and maintain diverse fishing opportunities. Currently, fishery managers provide different fishing opportunities – an estuary fishery and a non-estuary fishery – to meet different angler interests, with the Wauna Powerlines (RM 40) serving as a rough dividing line between the two areas (J. North, ODFW, personal communication). Downstream of the Wauna Powerlines, fishing occurs seven days per week for a limited period, lasting through at least 4 July of each year. To help achieve this, the minimum size limit for this area has been increased to 103 cm (41 inches) FL each May when seasonal estuary abundances increase, and closed to retention from 1 May to Mother's Day annually. Increasing the minimum size for retention during this time period reduces the overall catch rate of legal-sized fish, thereby reducing the rate at which the quota is achieved, and extending the fishing season. Catch-and-release fishing is allowed during non-retention periods. Above the Wauna Powerlines, the fishing season is longer, but retention is only allowed on Thursdays, Fridays, and Saturdays. Retention is often prohibited during August and September to ensure harvest opportunities through the fall. Catch-and-release angling is allowed on non-retention days.

In 1996, a no-fishing sanctuary was established downstream of Bonneville Dam to Beacon Rock (4.5 river miles) to protect spawning white sturgeon from the burgeoning boat-based catch-and-release recreational fishery targeting large fish. The recreational closure initially included the months of May and June, but it was extended through mid-July beginning in 2000. The 2006 Accord extended the sanctuary an additional 1.5 miles (2.4 km) downstream to U. S. Coast Guard Navigation Marker 85. The 2006, 2010 and 2011 Accords also recommended basic monitoring of increasing predation on white sturgeon by marine mammals. Since 2010, all sturgeon angling has been prohibited from May through August in the reach from Bonneville Dam to marker 82 (approximately nine miles downstream) to protect adult fish.

A no-fishing sanctuary also exists on the lower Willamette River. Fishing in the lower Willamette River, including catch-and-release, is prohibited between the I-205 Bridge and Willamette Falls from May 1 through Aug. 31 to protect spawning white sturgeon.

4.3.2 Bonneville Dam to McNary Dam (Zone 6)

White sturgeon fisheries in Zone 6 consist of treaty-Indian commercial and subsistence fisheries and non-Indian recreational fisheries. Non-Indian fishing is restricted to hook-and-line recreational fishing only, while treaty Indian fishing (commercial and subsistence) is conducted with three types of gear: hook-and-line, setlines, and gillnets.

Zone 6 commercial and recreational fisheries are managed in accordance with catch guidelines set forth by the Sturgeon Management Task Force (SMTF). Each year, the Columbia River Compact and the tribes set specific seasons for commercial gillnet fisheries. Under permanent regulations, treaty setline fisheries are open in all three Zone 6 reservoirs during January 1–31. Setline seasons target sturgeon, while gillnet seasons usually target steelhead; however, in recent years the winter gillnet season has shifted to target sturgeon due to poor prices for steelhead. Treaty Indian subsistence seasons are open the entire year, as were recreational seasons prior to 1994. Since 1994, the sturgeon recreational fishery and treaty Indian commercial fisheries have been managed under reservoir-specific quotas. Catch-and-release recreational fishing is allowed once recreational quotas are reached.

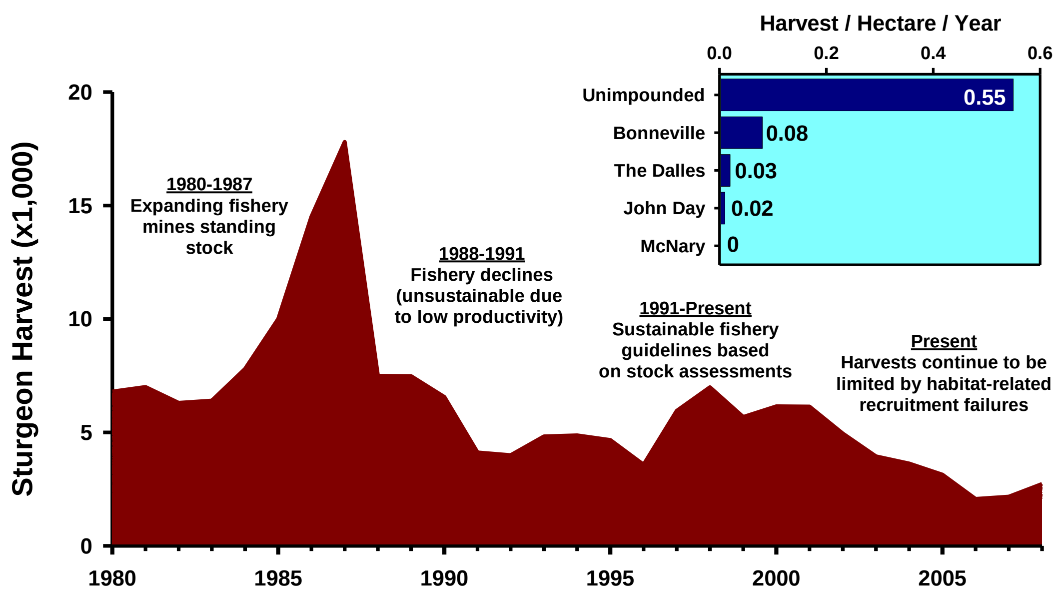


Figure 22. Annual harvest of white sturgeon from mid-Columbia impoundments upstream from Bonneville Dam and relative productivity based on 2008 harvest guidelines which are derived from sustainable harvest rates at current population levels (data from NPCC 2004; ODFW & WDFW 2008; Mallette 2008).

The current harvest allocation is approximately 40 percent recreational and 60 percent treaty for Zone 6, although reservoir-specific guidelines are shaped in response to fishery objectives. The recreational fishery is allowed a greater share of the catch in Bonneville Pool, while the treaty Indian fishery is allowed a greater share of the catch in The Dalles and John Day pools. Treaty Indian fishermen may continue to take sturgeon for subsistence purposes after commercial seasons have been completed, and this catch is not included in the commercial catch guidelines. Subsistence catch is estimated through a monitoring program conducted by the Yakama Indian Nation.

Table 7. Annual catch estimates and guidelines for commercial and recreational fisheries in Zone 6, 2001–2010.

	Bonneville Pool		The Dalles Pool		John Day Pool	
Year	Catch	Guideline	Catch	Guideline	Catch	Guideline
			Commercial Fisheries			
2001	1,287	1,300	1,215	1,100	755	1,160
2002	472	1,300	1,152	1,100	326	335
2003	379	1,200	811	900	251	335
2004	464	400	975	900	309	335
2005	550	400	809	900	360	335
2006	153	400	397	550	312	335
2007	285	400	607	550	232	335
2008	744	400	571	550	277	335
2009	431	400	862	1,000	325	335
2010	1,540	1,400	1,184	1,000	302	335
2011	2,089	2,000	604	1,000	1,208	1,000
2012	2,203	2,000	996	1,000	1,347	1,000
			Recreational Fisheries			
2001	1,426	1,520	677	700	299	560
2002	1,560	1,520	878	700	187	165
2003	1,542	1,700	447	400	186	165
2004	852	700	530	400	229	165
2005	588	700	384	400	132	165
2006	727	700	93	100	183	165
2007	682	700	108	100	249	165
2008	841	700	128	100	164	165
2009	638	700	216	300	146	165
2010	1,451	1,400	336	300	159	165
2011	2,334	2,000	220	300	533	500
2012	1,836	2,000	278	300	471	500

Fishery managers have designated two no-fishing sanctuaries in this reach of the Columbia River to protect spawning white sturgeon. The Columbia River from the Rufus grain elevator upstream to John Day Dam in The Dalles Pool, and from McNary Dam to the I-82 Bridge are closed to all fishing (retention and catch & release) from May 1 through July 31.

4.3.3 Columbia River upstream of McNary Dam

Sturgeon harvest in the McNary Pool is limited to recreational fisheries since treaty fisheries are restricted to the Zone 6 area. Harvest is monitored through angler catch record cards. A harvest guideline is not in affect for this area. Historically, the fishery was open for retention year round, but season restrictions have recently been implemented.

The Priest Rapids sturgeon spawning sanctuary extends from Priest Rapids Dam downstream approximately 2.5 miles to the boundary marker on the river bank 400 feet downstream of the Priest Rapids Hatchery outlet channel (Jackson Creek). The area that is closed to all fishing during the white sturgeon spawning season.

4.3.4 Upper Columbia

The recreational sturgeon fishery in the Canadian upper Columbia has been severely limited since 1960 and closed completely in 1996. 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 until prohibition after 1 April 1996. The closure included the Kootenay River downstream of Brilliant Dam and the Pend d'Oreille River downstream of Waneta Dam.

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.

4.3.5 Snake River

White sturgeon fisheries in the lower Snake River between Ice Harbor and Lower Granite dams consist of modest year-round non-Indian recreational fisheries in which retention is allowed. Regulations include daily and annual bag limits and a 43-inch FL minimum and 54-inch FL maximum size slot. Harvest is monitored through catch-record-card reporting.

There is still high demand for sturgeon among recreational anglers, even with the present sport fishing catch-and-release regulations in the middle and upper Snake River. Within Idaho, the IDFG is the lead agency responsible for white sturgeon management and recreational fisheries; however, along the shared state boundaries with Oregon and Washington there is active cooperation with ODFW and WDFW.

Given the current status and productivity of wild populations, no harvest opportunity is expected to be offered for the foreseeable future. Other than the above fishing regulations, there are no other gear restrictions required when fishing for Snake River white sturgeon. In the state fishing rules, the IDFG suggests the use of specific terminal tackle but does not currently require the use of such tackle (e.g., circle hooks, monofilament vs. braided line).

The IDFG continues to provide barbless hook, catch-and-release fishing opportunity for Snake River white sturgeon. To minimize angling-related stress and mortality, anglers are prohibited from removing white sturgeon from the water once caught. However, little is known about the cumulative impact of repeated catch-and-release. Because anglers increasingly recognize that "large" sturgeon can readily be hooked in the C.J. Strike tailrace, this area has become a very popular area to fish for sturgeon on the Snake River. Angler catch records below C.J. Strike Dam indicate that anglers spent 3,675 days during 1994 to catch 1,550 sturgeon, making this the most intensively fished section for white sturgeon in Idaho (IDFG 1995). Additional fishing restrictions are an option to be considered by the IDFG depending on population surveys, continuing research on mortality sources, and policy direction from the Idaho Fish and Game Commission.

The area below Ice Harbor Dam is closed to fishing from May 1 to July 31 to protect spawning adult white sturgeon.

5 OVERVIEW OF LIMITING FACTORS & THREATS

Several factors and threats greatly influence the health of white sturgeon populations in the Columbia and Snake Rivers. This chapter presents an overview of the primary factors that have affected white sturgeon across the Columbia River system. Chapter 7 provides more discussion on the limiting factors and threats that influence the populations within each management unit. Limiting factors are generally defined as the biological and physical conditions that limit a species' viability (e.g., high water temperature); threats are those human activities or natural processes that cause the limiting factors.

5.1 Habitat Fragmentation

While dam construction was not responsible for the historical decline of white sturgeon, impoundment has been the primary impediment to rebuilding of inland populations (Beamesderfer et al. 1995). Prior to construction of the FCRPS, Columbia River white sturgeon below Bonnington Falls (Kootenay River, British Columbia, Canada) and Shoshone Falls (Snake River, Idaho, U.S.A.; Setter and Brannon 1992; IPC 2005; Paragamian et al. 2005) were one freely mixing population, able to move throughout the Columbia Basin. Construction of the FCRPS dams throughout the Columbia Basin fragmented the once free-flowing river and altered the hydrograph in critical white sturgeon habitats (Parsley et al. 2007).

River fragmentation reduces the quality and quantity of habitat, alters migration patterns, and, despite limited upstream movement at a few dams, may impose unidirectional (downstream) gene flow (Jager 2006). 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.

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 23). 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 eight reaches, and are likely to become extirpated in another eight reaches without intervention. Remaining subpopulations are primarily restricted to reaches with significant riverine habitat. Subpopulations in marginal habitat areas have been lost, or consist solely of a few remnant individuals. Habitat fragmentation affects all life stages of white sturgeon.

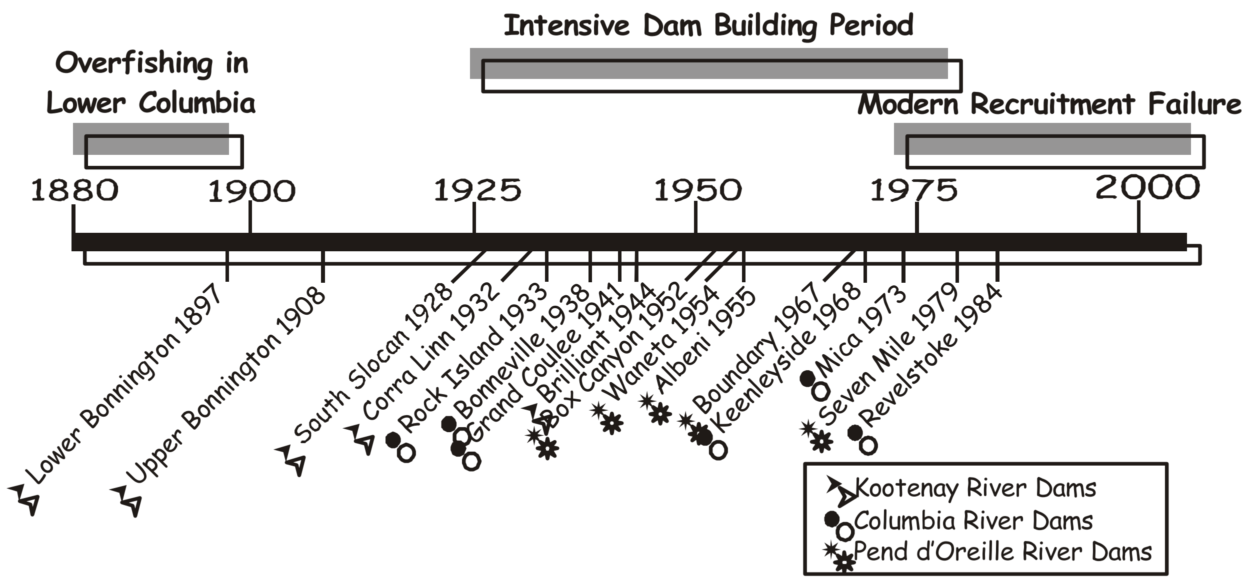


Figure 23. Time line of dam construction and white sturgeon impacts affecting upper Columbia River basin white sturgeon.

Fish ladders have been largely unsuccessful for passing sturgeon (Warren and Beckman 1993). Following completion of Bonneville Dam in 1938, initial passage efforts with fish elevators were somewhat effective for sturgeon. About 4,500 subadult sturgeon were passed upstream by fish elevators through 1956. However, use of elevators was discontinued as ladders proved to be much more efficient for upstream passage of salmonids.

A significant impediment to the consideration of potential passage measures for sturgeon has been their potentially confounding impacts on salmon. Adult passage systems are constructed, calibrated and maintained at each dam to optimize salmonid passage and changes in these systems to attract and pass sturgeon are likely to reduce salmon passage success.

5.2 Habitat Complexity, Quantity and Quality

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. Historical floods helped maintain channel diversity by periodically scouring and rearranging materials to create pool and backwater habitats. Today, regulated flows result in a more uniform river channel and an armoured substrate. A variety of in-water work activities, including channel maintenance, construction, and gravel extraction, as well as commercial navigation occur in different reaches of the Columbia and Snake Rivers, and may affect white sturgeon throughout all life stages.

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 that may be used directly by sturgeon or by important food sources.

In the lower Columbia River, dredging spoils may be pumped into upland holding ponds, dumped into the water column for dispersal or disposed of in shallows and on islands, and may result in direct mortalities of white sturgeon entrained in the dredging device, decreased survival of white sturgeon eggs, and impacts to important native prey species, such as eulachon. Dredging activities in areas where embryos and larvae are present can result in direct mortality. Additionally, dredging can alter or destroy juvenile and adult habitat in other sturgeon species (Kynard 1997). Pile rows have also been added to the lower river to help maintain the shipping channel and exist in many potential white sturgeon habitats; however their importance to, or effect on, white sturgeon have not been studied. Commercial shipping and/or recreational vessels ply nearly all waters in the lower Columbia River downstream of Bonneville Dam, and how these vessels interact with white sturgeon in this reach is poorly understood. Some pile rows in the lower Columbia River are currently under consideration for removal. These pile rows provide structure and velocity refuges, and may provide habitat for species that prey on rearing white sturgeon. They may also have negatively altered sturgeon rearing habitat.

5.3 Flow & Flow Variation

Before the development of the hydrosystem, Columbia River flows were characterized by high spring runoff from snowmelt and regular winter and spring floods. Records demonstrate that post-FCRPS construction spring freshet flows have been reduced by more than 50 percent (Quinn and Adams 1996; Quinn et al. 1997; ODFW unpublished data), as water is stored for flood control, power generation, irrigation and recreational use. At the same time, Columbia River winter flows have increased about 30 percent (NPCC 2004).

Construction of the mainstem dams has blocked access to historic spawning habitats in the lower Columbia River. White sturgeon prefer to spawn in high velocity habitats (Parsley et al. 1993; Perrin et al. 2003). The only area known to consistently provide suitable spawning habitat in the lower Columbia River exists immediately downstream of Bonneville Dam, where dam discharge creates the high water velocities necessary for white sturgeon spawning (Parsley et al. 1993; McCabe and Tracy 1994). The area of suitable spawning habitat is known to be directly linked to the amount of spill at key times during the spawning cycle of white sturgeon (Parsley et al. 1993; Parsley and Beckman 1994). Additionally, seasonally flooded habitats used for rearing may be impacted by flows out of Bonneville Dam (van der Leeuw et al. 2006). Flow and flow variation are believed to affect all life stages of white sturgeon. Reduced flows during spring and early summer (the spawning time of white sturgeon in the Columbia River basin) have been correlated to reduced recruitment of age-0 white sturgeon in the lower Columbia River (Parsley and Beckman 1994).

No flow measures have been implemented to date for the specific benefit of impounded sturgeon populations in the mid-Columbia and lower Snake rivers. Research has identified flow conditions that produce significant sturgeon recruitment in most dam tailraces, but sturgeon spawning needs must compete with other needs for water including power generation, irrigation, and measures for the benefit of ESA-listed salmon and steelhead. Flow and other operational measures implemented for salmon have also failed to restore consistent sturgeon recruitment (Mallette 2008).

Spawning habitat availability is a key determinant in the productivity of impounded sturgeon populations. Most reservoirs and impounded river segments no longer provide suitable spawning conditions under many or all flow conditions. Spawning habitat is generally limited to the high-energy zones of dam tailraces but tailrace hydro-geomorphology results in variable spawning habitat suitability and varying sensitivity to flow. The Dalles Dam tailrace at the head of Bonneville Reservoir appears to provide suitable spawning habitat under most flow conditions, hence, consistent sturgeon recruitment occurs to the Bonneville Reservoir population (Figure 24). In contrast, recruitment below John Day, McNary, Lower Monumental, and Lower Granite dams is sporadic, because suitable habitat is provided only in years of high spring runoff.

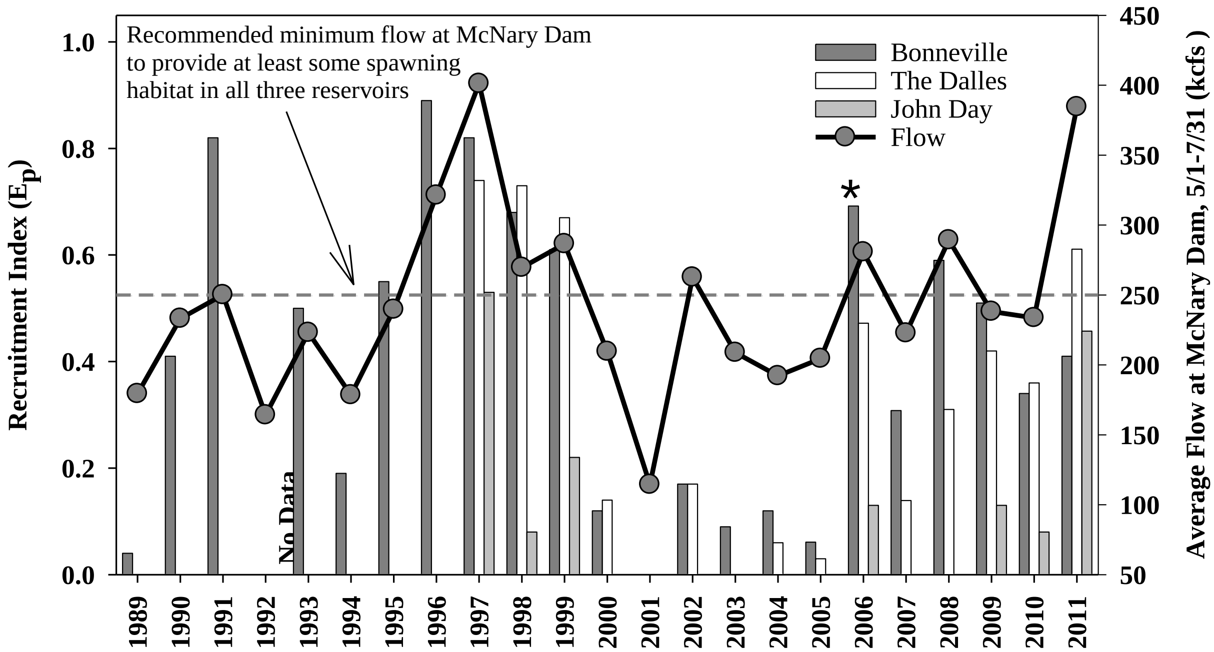


Figure 24. Recruitment index (Ep) for white sturgeon in Bonneville, The Dalles, and John Day reservoirs, and average daily flow at McNary Dam (May-July). *In 2006 age-0 indexing in Bonneville Reservoir switched from USGS trawl surveys to ODFW/WDFW/CRITFC gillnet surveys.

5.4 Water Quality

Temperature

Significant temperature changes have accompanied construction and operation of dams and reservoirs. 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). Sturgeon trapped in some fragmented reaches of the basin may no longer have access to temperatures suitable for spawning.

The States of Idaho, Oregon, and Washington, and the EPA are working in coordination with the Columbia Basin tribes to develop total maximum daily loads (TMDLs) 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 the State of Washington, the Department of Ecology WDOE has been charged with TMDL development.

Pollutants and Contaminants

White sturgeon can absorb a variety of pollutants and contaminants through direct contact or bioaccumulation through the food chain. 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.

As opportunistic bottom feeders, sturgeon frequently come into contact with sediments that could contain sediment-absorbed hydrophobic pollutants such as Polychlorinated biphenyls (PCBs), chlorinated pesticides, and chlorinated dioxins and furans (Webb 2002). These contaminants could be ingested incidentally during normal feeding, or contained in food items and bioaccumulated. Endocrine disrupters and carcinogens such as chlorinated pesticides (e.g., DDT) and PCBs have been detected in white sturgeon sampled throughout the Columbia River Basin (Kruse 2000; Foster et al. 2001a and 2001b; EPA 2002).

Because white sturgeon are a long-lived species, they have increased opportunities for exposure to and bioaccumulation of contaminants. There may be a link between contaminants and reduced growth and reproduction (Foster et al. 2001a, 2001b; Webb et al. 2006, Feist et al. 2005); however, to date, all studies investigating the link between these pollutants and adverse effects on white sturgeon have been correlative in nature and exact effects have not been determined.

Environmental contaminants have been detected in Columbia River water, sediments, and biota at concentrations above available reference levels (citation needed see NPCC 2004). Elevated levels of PCBs, dioxins/furans, and other harmful contaminants have been identified in lower Columbia River fish and sediment samples (ODHS 2008). In general, contaminant concentrations are often highest in industrial or urban areas, but may be found throughout the Columbia River mainstem and estuary as a result of transport and deposition mechanisms (NPCC 2004). Numerous contaminants have been detected in research activities conducted on white sturgeon throughout the Columbia River Basin (Kruse 2000; Foster et al. 2001a and 2001b; EPA 2002). White sturgeon may uptake contaminants through direct contact or bioaccumulation through the food chain.

The impounding of most Columbia River reaches has resulted in increased exposure of sturgeon to contaminants trapped in sediments behind the dams. Tissue samples (liver, gonad, and cheek muscle) collected from immature white sturgeon in the estuary, Bonneville, The Dalles, and John Day reservoirs have been analyzed for chlorinated pesticides, PCBs, mercury and physiological, molecular, and biochemical measures of growth and reproductive physiology. The results suggest a link between contaminants and reduced growth and reproduction (Foster et al. 2001a, 2001b; Webb et al. 2006, Feist et al. 2005), and may affect all life stages of white sturgeon to some degree.

Effects can vary from reduced condition factor (Foster 2002), reduced reproductive success (Webb 2002), or elevated mortality of early life stages (Kruse 2000). While exposure to contaminants may not be lethal to adult sturgeon, the conditions may present barriers to the development of early life stages. In studies conducted on Kootenai River white sturgeon, Kruse (2000) found a significant positive correlation between PCB concentrations in embryos and mortality. Kruse found that PCBs, heavy metals, and DDT (or its metabolites) were found to bioaccumulate in ovarian tissue. Kruse also indicated that larger eggs, characteristic of older adults, were more susceptible to increased exposure and had higher total organochlorine concentrations, a finding the confirmed bioaccumulation of these compounds in sturgeon eggs. Even more compelling, Kruse (2000) exposed incubating Kootenai River white sturgeon embryos to three test habitats. These test habitats included filtered river water, unfiltered river water, and unfiltered river water with river sediments. Survival in the group exposed to filtered river water was significantly higher than survival in the other test groups, suggesting that the sediments may have included contaminants that lower incubation success.

White sturgeon may be very sensitive to heavy metal (e.g., copper, mercury) accumulation (USFWS/USGS 2008). 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. Though white sturgeon appear to be lethally affected by relatively small amounts of metals such as copper, the exact extent of these metals in the Columbia River Basin is unknown.

Our understanding of the exact effects that pollutants and contaminants have on white sturgeon is limited. Laboratory studies have shown some pollutants to be particularly toxic to white sturgeon, and correlative evidence suggests that white sturgeon may be susceptible to bioaccumulation of environmental pollutants because of their life history characteristics (long-lived, late-maturing, benthic association, piscivorous at larger sizes) (Foster et al. 2001a, 2001b; Feist et al. 2005; Webb et al. 2006). However, no direct link between pollutants and contaminants and abundance has been established yet.

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.

Total Dissolved Gases

Dam construction and operation has increased dissolved gas to supersaturation levels downstream from several mainstem dams. 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.

5.5 COMPETITION AND PREDATION FROM CHANGES IN FISH COMMUNITIES

5.5.1 Predation

Pinnipeds

Predation by pinnipeds, Steller sea lions (*Eumetopias jubatus*), California sea lions (*Zalophus californianus*), and harbor seals (*Phoca vitulina*) on white sturgeon occurs in the Columbia and Willamette Rivers downstream of Bonneville Dam and Willamette Falls. Bonneville Dam and Willamette Falls restrict white sturgeon from upstream movement, hence, increasing their vulnerability to marine mammal predation in these areas. Furthermore, flow conditions in these areas are ideal for white sturgeon spawning, attracting large numbers of spawning-sized fish to the area, where they can become vulnerable to predation by pinnipeds. Predation by pinnipeds has increased sharply in recent years (Tackley et al. 2008a; ODFW, unpublished data).

Piscivorous Fishes

Substantial changes in the relative composition of fish species have accompanied introduction of exotic species and development in the Columbia River. Impacts on sturgeon from changes in the resident fish community are poorly understood, but predator and prey species are likely affected. Species such as rainbow trout, northern pikeminnow (*Ptychocheilus oregonensis)*, suckers (*Catastomus spp.)*, and walleye (*Sander vitreus)* may prey on white sturgeon eggs, larvae, and small juveniles. In fresh water, predation appears to be an important issue only for early life stages of white sturgeon, before age-1. In the estuary and ocean, predation on juvenile and subadult sturgeon is also likely. This section discusses piscivorous fish predation on white surgeon at the egg, larvae, and juvenile life stages.

<u>Eggs.</u> Demersal white sturgeon embryos are vulnerable to fish predation (Anders 1994, 1996; Miller and Beckman 1996; Parsley et al. 2002). During 1994 and 1995, biologists analyzed 632 stomach content samples collected from piscivorous fishes (northern pikeminnow, peamouth chub (*Mylocheilus caurinus)*, and suckers) in the Kootenai River (Anders 1996). They collected 428 naturally spawned white sturgeon eggs collected, 12.2 percent (52) were collected from 623 predatory fish stomach samples analyzed. Miller and Beckman (1996) reported the occurrence of one to 70 white sturgeon eggs in guts of four omnivorous fishes in the Columbia River. These authors noted that a single largescale sucker consumed 70 white sturgeon eggs.

Larvae and juveniles. Recent empirical research revealed species-specific predatory behavior by several Columbia River omnivorous fish species on young-of-the-year white sturgeon (Gadomski et al. 2000, 2001, 2002). Researchers reported that adult northern pikeminnow and channel catfish (*Ictalurus punctatus*) (16-24 inches [400-600 mm]) ingested sturgeon juveniles up to about 5 inches (120 mm). Similarly sized adult walleye ingested almost no sturgeon juveniles. However, juvenile walleye (6-8 inches [150-200 mm]) ate sturgeon larvae and juveniles up to about 1.6 in (40 mm). Prickly sculpins (4-8 inches [100-200 mm]) ate sturgeon up to 2 inches (50 mm). When rock substrate was available, fewer sturgeon larvae were ingested by sculpins. When equal numbers of alternate prey were available, sculpins presented with both sturgeon and goldfish ate more sturgeon. When smaller sturgeon and coho salmon prey were available, pikeminnow consumed both about equally. When sturgeon and coho prey were both larger, more coho were ingested (Gadomski et al. 2000, 2001, 2002). Thus, predation appears to be an important natural mortality factor, at least with white sturgeon age-0 and younger life stages. Beyond age-0, body size and scute development appeared to function as successful anti-predatory mechanisms.

5.5.2 Competition

The high fish content in the adult sturgeon diet suggests that they likely compete with piscivorous fishes for food, as well as over wintering habitat in some areas. These piscivorous fishes potentially include adult bull trout, burbot, northern pikeminnow, and prickly sculpin (Northcote 1954; Ford et al. 1995). Owing to the predominace of invertebrates in their diet, juvenile sturgeon could compete with kokanee, whitefish, rainbow trout, burbot, peamouth, suckers, and redside shiners. Intraspecific competition and density-dependent effects on population dynamics are likely to be much more important for white sturgeon than interspecific competition. The potential for intraspecific competition between juvenile and adult is limited by diet shifts as larger fish are able to capitalize on larger prey, particularly including adult lamprey, shad, and salmon.

5.6 Exploitation & Illegal Harvest

The magnitude of Columbia River white sturgeon indirect mortality related to recreational and commercial fishing activities is unknown, though some indirect mortality likely occurs. Carcass surveys conducted by WDFW routinely find deceased white sturgeon with fishing hooks embedded internally or external scars on the tongue, mouth, or gills (WDFW unpublished data). Rarely have gillnet scars been noted on deceased sturgeon (only one since 2004); however, it should be noted that the carcass surveys occur upstream of rkm 207, and most commercial sturgeon fisheries occur downstream of this point (C. Kern, ODFW, personal communication). In addition to the circumstantial evidence of indirect fishing related mortality, white sturgeon also exhibit a hormonal (plasma cortisol) stress response when they are handled by commercial or recreational fishing gear (ODFW, unpublished data). Cumulative stress has been shown to cause delayed mortality and reproductive failure in other fish species.

Although illegal harvest (poaching) of white sturgeon in the Columbia River is almost certainly an ongoing problem, the extent and magnitude of these removals is currently not quantifiable.

5.7 CLIMATE PATTERNS & TRENDS

Global climate change is likely to have a variety of effects on the Columbia River Basin and the white sturgeon populations within (ISAB 2007). Specific effects and corresponding white sturgeon responses to climate change are currently not well understood. While the thermal tolerance range of adult white sturgeon may be quite broad, several studies document temperature requirements for spawning and egg incubation and survival. Spawning of the Columbia River white sturgeon typically occurs between 10° and 18° C with the peak spawning from 13° to 15° C (Parsley et al. 1993), usually in June. Egg mortality increases when incubation reaches 18° C and total egg mortality occurs at 20° C (Wang et al. 1985). In the Kootenai River, white sturgeon spawn in May or June; however, water temperatures are much cooler, about 8° to 9° C, and spawning ceases by 12° C (Paragamian et al. 2001; Paragamian et al. 2002). Eggs incubated at cooler than optimal temperatures develop normally but take longer to hatch (Wang et al. 1985). Two other factors that influence successful white sturgeon recruitment may also be impacted by climate change: the high water velocities that now occur primarily in tailrace areas below hydroelectric dams in the Columbia River Basin (Parsley et al. 2002) and the availability of submergible riparian rearing habitat (Coutant 2004).

Under future scenarios of warming water temperatures and reduced summer flows, there is a likely possibility that white sturgeon may be stimulated to spawn earlier than the May–June period. This may actually be advantageous for white sturgeon for both egg incubation/survival, as well as flow/velocity requirements for successful recruitment. However, if white sturgeon do not spawn earlier due to warming water temperatures, the predicted lower summer flows may decrease or extinguish the already almost non-existent recruitment in the Columbia River Basin (ISAB 2007).

6 COMPREHENSIVE PLAN

This chapter describes a comprehensive vision, goals, and strategies for sturgeon encompassing all areas throughout the basin. These overarching plan elements were identified in a 2009 workshop focused primarily on sturgeon issues in the lower basin but are also generally applicable to sturgeon efforts throughout the region.

the thoughts of representatives from state and federal agencies, Indian Tribes, and other organizations with management and mitigation authority or responsibility, and specific knowledge and expertise on sturgeon in the region. These different representatives participated in the series of White Sturgeon Strategic Planning Workshops held in support of the framework development process. Together, they applied a broad range of scientific, technical and management expertise to identify opportunities for complementary planning, and examine critical uncertainties and needs for integration of efforts within and among different areas.

6.1 VISION

The following vision is for sturgeon 20 to 50 years in the future:

> *Abundant and diverse white sturgeon populations and optimum sustainable fisheries throughout the historical range, achieved by a combination of natural production and careful supplementation, and supported through an adaptive, collaborative, coordinated, science-based mitigation, management, monitoring, and evaluation program.*

Seven basic elements are incorporated into this vision: sustainability; natural production; biological characteristics; an inclusive program scope; effective monitoring, research, and evaluation; and rebuilding/mitigation.

6.2 GOALS & OBJECTIVES

Three goals identified during the white sturgeon workshops define further direction to help attain the shared regional vision. These goals enjoyed broad support among workshop participants. They include elements from a variety of possible goals that different participants proposed during the planning session and reflect the group's desire to define biological goals consistent with long-term conservation of the sturgeon populations, and to support beneficial uses of these populations for fisheries and harvest.

Objectives, also defined by participants during the white sturgeon workshops, provide further direction for achieving the shared regional vision. The following objectives, shown under each goal, further describe the characteristics that workshop participants wish to achieve for the different white surgeon populations. These objectives define biological characteristics such as abundance, natural recruitment, age structure and distribution consistent with long-term population viability; desirable fishery harvest and yield levels; and habitat conditions related to sturgeon status and production.

Goal 1: Viable, persistent populations throughout their historical range, where feasible.

Related objectives:

- Population(s) have high probability of persistence over several generations
- Natural spawning and recruitment to extent possible with available habitat
- Increased or expanded natural production potential
- Consistent recruitment through harvestable size range adequate to sustain natural spawning population
- Broad, stable age class structure for juveniles and adults
- Abundance consistent with natural carrying capacity and yield potential
- Stable genetic diversity comparable to historic levels
- Populations distributed throughout the historic range where habitat is suitable

Goal 2: Significant, stable and sustainable fisheries and harvest

Related objectives:

- Annual harvest optimized at current habitat capacity
- Fish populations that can support a potential target harvest or yield per geographic unit area
- Annual commercial fishing seasons that achieve meaningful economic benefits in appropriate areas
- Year-round sport fishing season retention fisheries in appropriate areas
- Meaningful number angler effort and number of fish available for harvest
- Shared benefits among the fisheries with recognition of regional distribution of access by different entities
- Fish health suitable for human consumption

Goal 3: Diverse, functional ecosystem supporting essential habitat, conditions, and resources

Related objectives:

- Flow regimes are conducive to spawning in terms of quality, quantity and timing
- Annual high quality temperature-conditioned spawning habitat as defined by Parsley and Beckman (1994) in area of focus
- Balanced or natural prey/predator balance in terms of managing natural white sturgeon mortality and native prey base

6.3 STRATEGIES

This section several potential strategies framed to improve coordination and collaboration of sturgeon management efforts across the Columbia River basin. The strategies help ensure the implementation of a scientific basin-wide approach that will allow us all to achieve our goals. They tackle several common limiting factors that can best be addressed through a basin-wide collaborative process. Not every strategy may be appropriate in every management unit. Chapter 7 provides more specific detail on area-specific implementation.

6.3.1 Improving Passage/Connectivity

Sturgeon are a highly mobile species and move, as needed, to take advantage of ever changing river conditions. Construction of the mainstem dams greatly restricted sturgeon movement and recruitment. The fish have been left to rely upon the resources in the location where they have been trapped. What was once a single population, or a series or broadly overlapping metapopulations, is now a series of fragmented subpopulations trapped in reservoirs. Sturgeon in the lower Columbia downstream from Bonneville Dam still have access to the ocean, and the population remains large and productive. The populations in impounded reservoir/river sections upstream from Bonneville Dam have not fared as well.

There are many potential benefits from providing sturgeon passage; most notably, gene flow, habitat connectivity, maximizing productivity, and increased harvest opportunity. However, there are also risks that need to be examined and considered before improving passage. Many of these risks are related to uncertainty and poor understanding of sturgeon movement, behavior and recruitment, and to increased management complexity.

Alternatives

- Develop clearly define goals and objectives for sturgeon passage up and down river.
- Identify opportunities to manually relocate trapped sturgeon during dam operations and maintenance.
- Investigate and identify effective methods to restore passage to allow for free interaction and movement.
- Consider sturgeon criteria when refurbishing existing ladders and fish structures.
- Consider moving fish around from areas of greater abundance to lesser if it will not impact recovery.
- Conduct research to gain a better understanding of sturgeon movement and behavior (perhaps telemetry studies). Studies should focus on obtaining a better sense of what habitat sturgeon are using, why they’re using it, and when they’re using it, and whether or not passage would help meet that need (feeding benefits vs. spawning benefits).

6.3.2 Habitat Restoration

White sturgeon historically ranged hundreds of miles to access diverse habitats. River conditions were extremely dynamic with large seasonal and annual variations in stream flow, temperature, and resource availability. Sturgeon developed life histories that allowed them to thrive in these river systems, and take advantage of scattered and seasonally available food resources, including other anadromous prey species.

Today, not only are many sturgeon populations isolated between dams, but the availability and suitability of habitat existing in a reach may restrict sturgeon production. Presently, much remains unknown regarding existing habitat and/or flow limitations, and the effect of these limitations on carrying capacity, spawning success, age-0 survival, etc. Efforts to improve sturgeon production in several of the different management units face similar issues and unknowns.

Alternatives

<u>Flow</u>

- Promote hydro system operations that improve natural production and recruitment
- Enhance natural production through flows
- Operate the FCRPS to provide flows consistent with aggressive non-breach hydro system operations
- Manage water budget to provide optimal spawning conditions
- Restore river flow pattern to natural hydrograph
- Minimize extremes in flow peaks and load following during the white salmon spawning season

<u>Contaminants</u>

- Reduce chemical contaminants in management area
- Sample fish of potential legal-size routinely for toxin levels, in each reservoir of the mid-Columbia, upper-Columbia and Snake River areas
- Establish a consensus as to what toxins should be tested
- Develop a rotational schedule that will assure no reservoir goes un-sampled for longer than 5-years

6.3.3 Fisheries Management

While there is an adequate system in place to account for removals associated with recreational and commercial harvest, the actual exploitation rate on white sturgeon in several parts of the basin is unknown. This is largely due to uncertainties surrounding the population estimates, uncertainties surrounding delayed mortality associated with released fish, uncertainties associated with removals outside the Columbia River, and uncertainties associated with tags that are shed prior to harvest or are unreported by fishermen.

Alternatives

- Describe fishery management goals
- Regulate harvest to be consistent with conservation objectives
- Establish fish size regulations that optimize fishery economic and opportunity benefits (re-evaluate slot limit of harvestable fish)
- Reduce impacts of fisheries when water temperatures are high

6.3.4 Hatcheries

The role of sturgeon supplementation in meeting future recovery and harvest goals is one of the most significant decisions facing regional sturgeon managers. Hatchery supplementation has been identified as a potential alternative for restoration of depleted sturgeon populations and fisheries in the mid-Columbia reservoirs (Fickeisen 1985a, 1985b; NPCC 2004). It is a viable alternative for sturgeon restoration in the absence of effective implementation of other beneficial measures including spawning flow increases, passage improvements, or transplants (Beamesderfer and Farr 1997; Munro et al. 2007).

Already, successful conservation hatchery programs have been developed for unique headwater populations of white sturgeon to bridge chronic habitat-related recruitment failures in the Kootenai River (Duke et al. 1999; Ireland et al. 2002a, 2002b; Paragamian and Beamesderfer 2004; Paragamian et al. 2005; KTOI 2007) and the transboundary upper Columbia River (Hildebrand et al. 1999; UCWSRI 2002; NRTWS 2006; Irvine et al. 2007). The Kootenai and upper Columbia sturgeon recovery programs have demonstrated the feasibility of using hatchery-spawned sturgeon from wild parents to preserve native genetic diversity, supplement failed natural recruitment, and increase abundance in certain situations. Use of wild broodstock in these conservation hatchery programs has been key to their objective of maintaining the natural genetic diversity of the population and avoiding potential detrimental impacts of hatchery selection or domestication.

Hatchery-produced sturgeon also provide a very useful experimental tool for applied research to determine limiting factors, habitat capacity, broodstock limitations, population parameters, and immigration/entrainment in natural populations. Many questions on the basic life history of these fish, fundamental to successful management, will be most effectively answered with an experimental approach involving controlled testing of potential management alternatives. A large body of inferential research on existing populations has answered many questions, but system manipulations are necessary to address other critical unknowns, including the life-stage specific carrying capacity of impounded reaches of the river. Monitoring of hatchery sturgeon released in the Kootenai and Upper Columbia has provided critical information on factors limiting natural production, system capacity, and life history bottlenecks (Ireland et al. 2002b; Golder 2007; Justice et al. 2009). Under current conditions of low recruitment, critical information often cannot be obtained by monitoring of natural populations alone because of low numbers and sampling power. Use of marked hatchery fish provides a known subject population and structured releases allow for the design of systematic statistical experiments.

Alternatives

- Develop science-based supplementation program to satisfy basin-wide sturgeon needs to establish sustainable sturgeon populations
- Utilize artificial propagation to mitigate for effects of ecosystem alteration on sturgeon population dynamics
- Utilize hatchery fish as experimental subjects for evaluating natural population status and life stage specific limiting factors
- Release hatchery reared sturgeon at regular intervals in reservoirs to recovery and maintain healthy age class structure
- Employ a combination of natural and artificial production consistent with segment-based productivity
- Use selected pools or river segments for supplementation and to evaluate results
- Add hatchery fish where natural production falls short of goals
- Maintain a self-sustaining natural origin component of population capable of providing adequate broodstock for supplementation needs
- Produce white sturgeon in supplementation hatchery program for release as juveniles and adults into management areas
- Develop Master Plan for basin-wide sturgeon supplementation needs
- Use family units in hatcheries
- Evaluate growth rates and food base in each pool/river segment to determine proximity to carrying capacity and possible adverse impact to high level hatchery augmentation
- Establish and implement genetic management guidelines for supplementation programs within the basin
- Collect source fish from diverse Columbia River populations
- Complete microsatellite analysis of all sub populations within the Basin to help develop science-based approach to maintain; or where appropriate, enhance
- Delineate effective hatchery techniques to optimize, maximize and establish quality productivity
- Initial hatchery operations may be developed on an experimental basis, utilize flexibility in addressing problems as they arise (don't try to anticipate all problems)
- Time is of the essence; we're running out of time. We need to initiate aggressive supplementation (hatchery) operations as expeditiously as possible. These sturgeon stocks will likely not recover on their own volition.
- Collaborative supplementation efforts where possible
- Conduct studies on the effect of toxins on the physical health of fish and their ability to produce viable offspring

6.4 MONITORING & EVALUATION

Success in our efforts to improve Columbia and Snake River white sturgeon populations demands implementation of a strategic adaptive management process. Adaptive management allows managers to manage in the face of uncertainty and learn by doing. It help us understand how and why the fish populations and their associated habitats respond to different management actions, and use these findings to better address key limiting factors and threats.

Alternatives

- Comprehensive RM&E program to assist with development and adaptive management of white sturgeon in management areas
- Conduct updated stock assessment through entire historic range to determine baseline status
- Complete individual population status ranking across basin/range
- In consultation with appropriate entities, fund intensive white sturgeon fishery management
- Periodic stock assessments in all pools
- Diverse age-class structure
- Identify spawning and rearing areas in each pool/river segment
- Monitor and evaluate interactions with introduced/invasive species
- Monitor and evaluate mitigative white sturgeon restoration activities and population responses to environmental conditions
- Monitor and evaluate sources of natural and unaccounted (delayed fisher impacts, illegal harvest, pollutants, etc.) mortality
- Monitor populations to determine amount of available production for harvest
- Provide consistency in supplementation, broodstock, and monitoring and evaluation methodology
- Define apparent genetic structure within Columbia Basin (i.e., what we have to work with today)

6.5 CRITICAL UNCERTAINTIES RESEARCH

Presently, much remains unknown about white sturgeon populations and habitats in various reaches of the Columbia and Snake Rivers. Managers in several of the different management units face similar issues and unknowns that could potentially impact the long-term success of their efforts to conserve and restore white sturgeon populations. Many of these unknowns and data gaps could best be addressed through a coordinated approach.

Alternatives

- Conduct research that addresses critical white sturgeon uncertainties.
- Conduct maternal transfer of contaminants toxicity evaluations to determine possible influence on survival, fitness, growth.
- Analyze contaminants in eggs
- Conduct early life stage toxicity tests with common contaminants in the basin to determine possible influence on survival and fitness

- Evaluate predator species and predation in each pool/river segment over multiple years – correlate to flow and turbidity
- Develop computer model in three years with inputs and outputs for defining and managing a persistent population in each pool
- Determine causes of recruitment or reproductive failure through testable hypotheses in each population
- Evaluate carrying capacity in each pool through evaluations of survival, growth, food abundance and entrainment.

6.6 Implementation

Achieving the goals and objectives defined above for Columbia and Snake River white sturgeon requires implementation of strategies and actions at the local, regional and basin levels. As discussed in Chapter 7, numerous activities are already underway to manage and improve white sturgeon populations in the different management unit.

Alternatives

- Science-based approach
- Implement a decision framework that integrates scientific information into management decisions
- Review existing plans
- Collaborative and coordinated basin-wide management
- Create a permanent working group with representatives from states, federal agencies, and tribal agencies to address management and propagation issues (upper, lower and mid Columbia Areas, PUDs)
- Achieve regional broadly inclusive information exchange forum
- Support development of 'technical teams' to facilitate information sharing and transmission to managers
- Information exchange, identification of regional program interaction, impacts resolution (e.g., what broodstock, etc. – NOT allocations)
- Conduct periodic progress briefings or meeting among collaborators
- Secure consistent and stable funding
- Solicit long-term support and funding from all conceivable sources based on that plan

7 MANAGEMENT UNIT SUMMARIES

This chapter discusses existing conditions and programs in nine management units for Columbia and Snake River white sturgeon. The following sections summarize existing conditions and management direction for white sturgeon in each management units: Lower Columbia (7.1), Lower Mid-Columbia (7.2), Upper Mid-Columbia (7.3), Transboundary Upper Columbia (7.4), Far Upper Columbia (7.5), Kootenay Lake and Kootenai River (7.6), Lower Snake (7.7), Middle Snake (7.8) and Upper Snake (7.9). Each section describes management unit status; limiting factors and threats; existing plans, objectives and strategies; existing programs, projects, actions and schedules; and needs and uncertainties.

7.1 Lower Columbia (below Bonneville Dam)

The lower Columbia River supports the most productive white sturgeon population in the world (DeVore et al. 1995). Due to the construction of the FCRPS, white sturgeon residing downstream of Bonneville Dam are the only population segment in the basin that can still access ocean and estuarine environments. As a result, the population has been able to maintain an amphidromous life history strategy, and have access to interchange pathways between Sacramento and Fraser River populations (Hanson et al. 1992). Available information (ODFW, unpublished data) indicates that while the majority of white sturgeon downstream of Bonneville Dam inhabit the mainstem Columbia River, they also inhabit the Willamette River (especially downstream of Willamette Falls), Oregon coastal rivers, estuaries, bays, and waters inside the 50 fathom line.

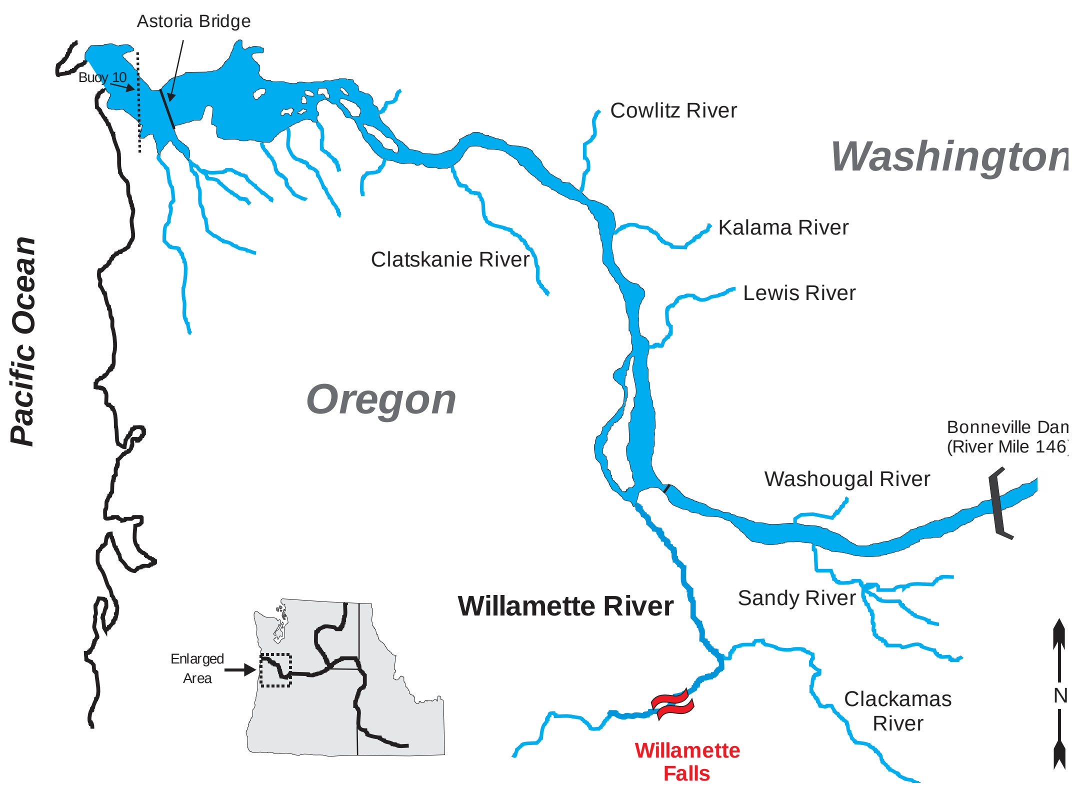


Figure 25. Map of the Lower Columbia management unit including the lower Willamette River.

7.1.1 Status

The lower Columbia River population is the most abundant and productive within the current Species Management Unit (SMU) and the Columbia Basin as a whole (Cochnauer et al. 1985; Beamesderfer et al. 1995; DeVore et al. 1995). Estimated numbers in the 38-54 inch size range peaked at around 200,000 in 1995 but have been declining since (Table 8). Declining numbers resulted in progressive reductions in sturgeon harvest culminating in an anticipated closure of sturgeon retention seasons in 2014.

Prior to 2010, sampling to mark and recapture fish was not conducted in a random manner. This non-random type of estimate is most useful for tracking abundance trends, but is less ideal for indicating specific abundance levels. While the non-random nature of marks and recoveries decreases this method's utility as a source for point estimates, it does provide an invaluable long-term population index. Beginning in 2010, the Oregon Department of Fish and Wildlife implemented a stock assessment program with a sampling regime designed to incorporate a random selection of sites. These assessments are improving and will continue to improve our understanding of the size structure and condition of the lower Columbia River white sturgeon population. These assessments have also provided a foundation for improving the accuracy of future population abundance estimates of lower Columbia River white sturgeon. This effort produced the first within-year population estimate for the lower Columbia River in 2010 (Jones 2010), and is the newly adopted methodology that ODFW intends to use in the future to estimate white sturgeon abundance in the lower Columbia River.

The 2011 abundance estimate for lower Columbia white sturgeon ≥ 81 cm FL was 210,000 ± 167,000 (estimate ± 95% confidence interval). ODFW estimated the abundance of juvenile (53–95 cm FL), sub-adult (96-165 cm), and adult (> 165 cm FL) white sturgeon to be about 587,000, 75,000, and 3,400 fish respectively (Jones 2011). Abundance was not estimated for fish smaller than 53 cm FL because they are infrequently captured on setlines, and these estimates do not include that portion of the population downstream of Bonneville Dam but outside the mainstem lower Columbia River (e.g., coastal estuaries and near-shore marine environments).

White sturgeon habitat use in the Willamette River above Willamette Falls is currently poorly understood (ODFW 2011). The reach, however, is assumed to support low white surgeon abundance compared to the mainstem lower Columbia River. From 1989–2003, the lower Columbia-Willamette area received periodic supplementation of juvenile white sturgeon produced from wild broodstock and reared in a private hatchery (ODFW, unpublished data); this population segment is currently believed to be primarily the result of the now discontinued hatchery stocking practices. The current status of these fish is largely unknown, though distribution appears to cover the extent of the mainstem Willamette River from its Columbia River confluence upstream to where it splits into Coast and Middle forks near the city of Eugene, Oregon, approximately river kilometer (rkm) 300 (river mile [RM] 186).

Table 8. Estimated abundance of lower Columbia River white sturgeon (by fork length interval).

Year	Historical estimation method 96-107 cm (38-43 in)	Historical estimation method 108-137 cm (43-54 in)	Historical estimation method 96-137 cm (38-54 in)	Setline method 96-137 cm (38-54 in)
1987	75,900	28,100	104,000	
1988	34,400	33,700	68,100	
1989	31,900	16,800	48,700	
1990	25,800	12,000	37,800	
1991	32,500	11,700	44,200	
1992	70,400	8,700	79,100	
1993	115,500	14,200	129,700	
1994	N/A	N/A	N/A	
1995	143,200	59,000	202,200	
1996	137,100	33,500	170,600	
1997	146,600	27,700	174,300	
1998	116,800	23,900	140,700	
1999	116,800	17,700	134,500	
2000	117,300	17,400	134,700	
2001	102,200	25,300	127,500	
2002	87,400	34,200	121,600	
2003	85,000	46,200	131,200	
2004	N/A	N/A	N/A	
2005	106,900	30,000	136,900	
2006	88,100	35,300	123,400	
2007	101,800	29,900	131,700	
2008	69,800	31,400	101,200	
2009	65,000	30,000	95,000	
2010	39,100	26,200	65,300	100,200
2011	46,700	28,100	74,800	80,500
2012	--	--	--	72,700

7.1.2 Limiting Factors & Threats

Although the lower Columbia River white sturgeon population is considered healthy and currently not at risk, critical constraints, limiting factors, and threats do exist that could compromise the population's long-term health. Potential limiting factors are summarized below and presented by life history stage in Table 9.

Marine Mammal Predation

Marine mammal predation affects rearing and spawning life stages of lower Columbia River white sturgeon. Predation by pinnipeds, Steller sea lions, California sea lions, and harbor seals, on white sturgeon in the Columbia and Willamette rivers downstream of Bonneville Dam and Willamette Falls has increased sharply in recent years (Tackley et al. 2008a; ODFW, unpublished data). Bonneville Dam and Willamette Falls restrict white sturgeon from upstream movement hence increasing their vulnerability to marine mammal predation in these areas. Furthermore, flow conditions in these areas are ideal for white sturgeon spawning; attracting large numbers of spawning sized fish to the area, where they become vulnerable to predation by pinnipeds.

Predation estimates of white sturgeon generated from observations near the tailrace of Bonneville Dam have increased annually from 442 in 2006 to 2,172 in 2010 (Tackley et al. 2008a; Tackley et al. 2008b; Stansell et al. 2010). The size of white sturgeon preyed upon by sea lions has decreased each year since 2006. The combined increase in numbers killed and decrease in size of fish caught by sea lions is reminiscent of over-fishing witnessed in certain human fisheries (Pauly et al. 1998; Allan et al. 2005) whereby the larger individuals are removed first and subsequent fishing removes smaller-sized individuals, and may indicate a similar phenomenon. Losses of adult white sturgeon are potentially more detrimental to the population than losses of sub-adults or juvenile, even if the actual number is fewer.

Habitat Fragmentation

Construction of the FCRPS dams throughout the Columbia Basin has fragmented the once free-flowing river and altered the seasonal hydrograph in critical lower Columbia River white sturgeon habitats (Parsley et al. 2007). Before the dams, white sturgeon moved freely through the Columbia River Basin, traveling between widely distributed spawning, rearing, and feeding habitats. Today white sturgeon in the lower Columbia retain access to the ocean, but are less able to redistribute from areas of high densities or poor resources to historically available spawning and rearing areas (NPCC 2004). Habitat fragmentation affects all life stages of white sturgeon

Habitat Diversity, Quality and Quantity

All life stages of lower Columbia River white sturgeon may be affected by available habitat quality and quantity. Development of shoreline and riparian zones for economic purposes has impacted and reduced complex lower Columbia River white sturgeon habitats through channelization, diking, dredging, and other practices. Loss or alteration of these complex spawning and rearing habitats will likely negatively affect white sturgeon abundance in the lower Columbia River. Direct relationships between habitat loss/alteration and lower Columbia River white sturgeon abundance are not well understood, with the exception of the spawning habitat to recruitment relationship.

A variety of in-water work activities, including channel maintenance, construction, and gravel extraction, as well as commercial navigation occur in the lower Columbia River. White sturgeon are known to use habitats where dredging occurs (Buell 1992; Romano et al. 2002), and there is evidence that dredging operations may attract white sturgeon (Parsley and Popoff 2004), potentially compounding losses. Dredging spoils may be pumped into upland holding ponds, dumped into the water column for dispersal or disposed of in shallows and on islands, and may result in direct mortalities of white sturgeon entrained in the dredging device, decreased survival of white sturgeon eggs, and impacts to important native prey species such as eulachon. Dredging activities in areas where embryos and larvae are present can result in direct mortality. Additionally, dredging can alter or destroy juvenile and adult habitat in other sturgeon species (Kynard 1997). Association with benthic habitats by North American sturgeons likely increases their susceptibility to dredging entrainment (Kynard 1997).

Pile rows have also been added to the river to help maintain the shipping channel and exist in many potential white sturgeon habitats; however their importance to, or effect on, white sturgeon have not been studied. Some pile rows in the lower Columbia River are currently under consideration for removal. These pile rows provide structure, velocity refuges, and may provide habitat for prey species of rearing white sturgeon, or they may have negatively altered sturgeon rearing habitat.

Commercial shipping and/or recreational vessels ply nearly all waters in the lower Columbia River downstream of Bonneville Dam, and how these vessels interact with white sturgeon in this reach is poorly understood. Commercial navigation could affect white sturgeon through direct impacts, displacement from preferred habitats, and sound and pressure disturbances in the form of propeller cavitation, engine noise, etc. in addition to the effects of dredging needed to maintain navigation channels.

Flow and Flow Variation

Before development of the hydrosystem, Columbia River flows fluctuated seasonally, with high spring runoff from snowmelt and regular winter and spring floods. Today, stream flow in the Bonneville Dam tailrace can vary hourly and daily because of electrical load following and power peaking for the hydrosystem (Kukulka and Jay 2003). Daily and hourly oscillations between high flow levels and tailwater elevations during peak power generating activities and low flow levels and tailwater elevations during off-peak demand can occur, especially at low to moderate river discharges. This daily load-following cycle and the ensuing changes in tailwater elevation, results in substantial areas of riverbed being subject to a recurring watered-dewatered loop.

Currently, the only area known to consistently provide suitable spawning habitat for white sturgeon exists immediately downstream of Bonneville Dam, where dam discharge creates the high water velocities necessary for white sturgeon spawning (Parsley et al. 1993; McCabe and Tracy 1994). This area of suitable spawning habitat is known to be directly linked to the amount of spill at key times during the spawning cycle of white sturgeon (Parsley et al. 1993; Parsley and Beckman 1994). Reduced flows during spring and early summer (the spawning time of white sturgeon in the Columbia River basin) have been correlated to reduced recruitment of age-0 white sturgeon in the lower Columbia River (Parsley and Beckman 1994).

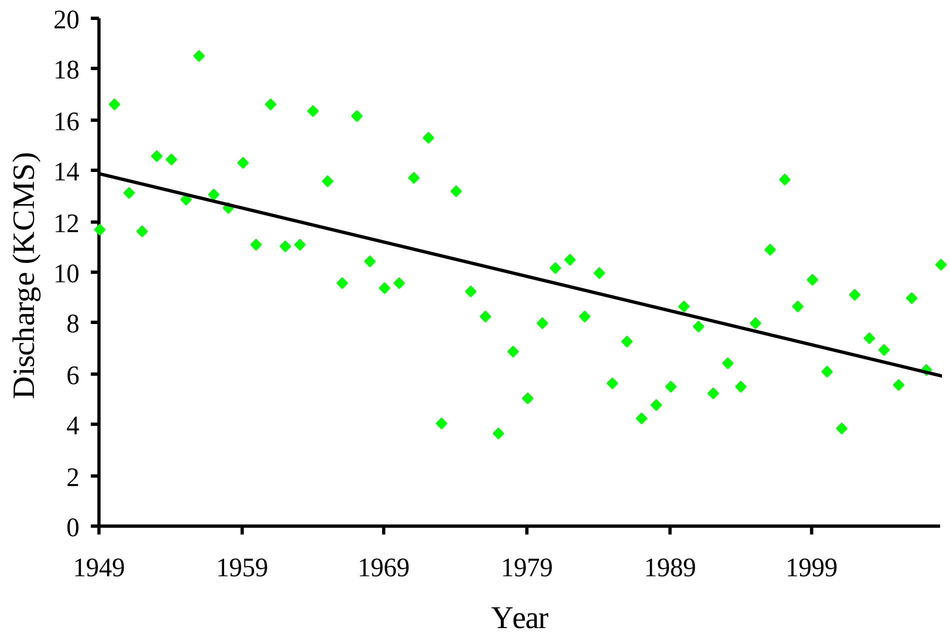


Figure 26. Average June discharge at Bonneville Dam, 1949 through 2009.

Water Quality

Temperatures

Water temperatures may act as a factor limiting white sturgeon spawning and recruitment. Peak spawning in the lower Columbia River occurs at 12 to 15 ºC (Parsley and Beckman 1994), though some may still occur at 18 to 20 ºC (McCabe and Tracy 1994). Optimum water temperatures for the development of white sturgeon eggs and larvae occur at 11 to 17 ºC with negative impacts to larval development at temperatures above 17 ºC (Wang et al. 1985). Hydrosystem operations can cause unnatural and early increases in river water temperatures (Quinn and Adams 1996) to levels detrimental to developing white sturgeon eggs and larvae (incubation and dispersal life stages). Early temperature increases, and increases above optimal temperature levels can adversely affect white sturgeon. Although FCRPS operations can and do affect the lower Columbia River thermo- and hydrographs (see Quinn and Adams 1996, it is currently unknown what effect this may have on the white sturgeon population.

Contaminants

Environmental contaminants have been detected in lower Columbia River water, sediments, and biota at concentrations above available reference levels. These contaminants are not as quickly evacuated from the system due to habitat changes in the estuary as they would otherwise be (Sherwood et al. 1990; NPCC 2004). Elevated levels of polychlorinated biphenyls (PCBs), dioxins/furans, and other harmful contaminants have been identified in lower Columbia River fish and sediment samples (ODHS 2008). In general, contaminant concentrations are often highest in industrial or urban areas, but may be found throughout the lower Columbia River mainstem and estuary as a result of transport and deposition mechanisms (NPCC 2004).

Research studies have detected numerous contaminants in white sturgeon throughout the Columbia River Basin (Kruse 2000; Foster et al. 2001a and 2001b; EPA 2002). White sturgeon may uptake contaminants through direct contact or bioaccumulation through the food chain. Our understanding of the exact effects that pollutants and contaminants have on white sturgeon is limited. However, laboratory studies have shown some pollutants to be particularly toxic to white sturgeon. Correlative evidence suggests that white sturgeon may be susceptible to bioaccumulation of environmental pollutants because of their life history characteristics (long-lived, late-maturing, benthic association, piscivorous at larger sizes) (Foster et al. 2001a; 2001b; Feist et al. 2005; Webb et al. 2006). No direct link between pollutants and contaminants and abundance has been established at this time.

Dissolved Gases

When water passes through the spill gates at dams on the Columbia River it may become supersaturated with atmospheric gases, potentially affecting white sturgeon in the vicinity of the spill. Construction of the FCRPS dams and their associated spill has created the potential for negative impacts to white sturgeon from dissolved gas supersaturated water. In a laboratory study, gas bubbles formed in the buccal cavity and/or nares were noticed at 118 percent supersaturation, and at 131 percent supersaturation more than 50 percent of larval white sturgeon died within 10 days of exposure (Counihan et al. 1998). Dissolved gases most likely affect the dispersal life stage. Our understanding of dissolved gas supersaturation impacts to white sturgeon is limited to laboratory studies that have noted some adverse effects of exposure to supersaturated dissolved gases (Counihan et al. 1998). However, sturgeons have adapted to poor respiratory flow from the buccal cavity, and this may make them less sensitive to dissolved gas supersaturation (Counihan et al. 1998).

Turbidity

Spring and summer turbidity levels in the Columbia River post-impoundment are lower than other unimpounded Pacific Northwest rivers (Gadomski et al. 2005a; Perrin et al. 2003). Construction of the FCRPS dams has contributed to decreased turbidity levels potentially increasing predation on white sturgeon eggs, larvae, and juveniles. Predation experiments have indicated that predation on larval white sturgeon by sculpin, a native piscivore, is negatively correlated to levels of suspended sediments, i.e., higher turbidities make it more difficult for predators to locate and capture white sturgeon larvae (Gadomski and Parsley 2005a). Low turbidity levels most likely affects incubation and dispersal life stages. Although decreased turbidity in the Columbia River due to construction of the FCRPS undoubtedly increases predation related mortality for early life stages of white sturgeon, the actual magnitude and corresponding impact on the population is currently poorly understood.

Fishery Effects

Lower Columbia River white sturgeon are subject to a variety of fisheries, and over-utilization could negatively impact the lower Columbia River white sturgeon population segment. If enough white sturgeon were removed, decreases in the numbers of white sturgeon reaching spawning sizes could reduce subsequent generations. Because of the monetary value of white sturgeon, particularly caviar, illegal harvest is a potential threat to white sturgeon populations. If the magnitude of established recreational and commercial fisheries were beyond sustainable levels these legal fisheries could slow the growth of or reduce the size of this population. The handling stress associated with catch-and-release of white sturgeon ≥ 65 inches FL (either targeted recreational catch-and-release fishing or release of fish incidentally encountered in pursuit of legal-size fish in both commercial and recreational fisheries) can negatively impact reproductive adults and thus, population productivity, either through direct mortality or decreased reproductive success (Schreck 2010; Webb and Doroshov 2011). Recent research has found a strong positive correlation between "play time" and stress hormones present in the blood and that white sturgeon captured by hook and line had higher levels than those captured via set-line (Webb and Doroshov 2011). White sturgeon carcass surveys conducted by WDFW frequently find deceased white sturgeon with evidence of hooking injuries, and with fishing tackle trailing from both the mouth and the vent (WDFW, unpublished data), although the cause of mortality is often not identified and may not be associated with fishing. Fishing effects on white sturgeon most directly impact rearing and spawning life stages.

The full extent of illegal harvest is difficult to measure. Currently, illegal harvest is monitored through the efforts of the Oregon State Police's Fish and Wildlife Division. In the lower Columbia River, The Oregon State Police reported 25 illegally harvested white sturgeon in 2008 and 48 in 2009. These are known illegal harvest numbers; the actual illegal harvest numbers are likely considerably higher. For example, in the mid-1990s a poaching ring based in Vancouver, Washington was exposed that had harvested approximately 2,000 adult sturgeon for 1.65 tons of caviar with an estimated value of $2,000,000 (Cohen 1997; Saffron 2002). In 2003, a white sturgeon poaching ring was apprehended with ties to both the Columbia and Sacramento rivers (Bailey 2003). If 2,000 adult white sturgeon were being removed annually in poaching related activities, this would account for approximately 10 – 15 percent of the current adult population (ODFW, unpublished data), and could be limiting. Because legal harvest is monitored and managed intensely, it is one of the few impacts that is easily quantifiable. Therefore, its impacts on the lower Columbia River white sturgeon population are better understood than many other factors.

There is no direct evidence between handling stress related to angling targeted at over-size sturgeon and reduced reproductive success in white sturgeon; though correlative evidence suggests there could be a link (Webb and Doroshov 2011), and deleterious effects associated with catch-and-release angling have been demonstrated in other fish species (Schreck et al. 2001; Beggs et al. 1980). However, a lot of variability exists surrounding these relationships in lower Columbia River white sturgeon – possibly because of multiple recaptures, i.e., even a fish that has been played for a relatively short time may have elevated stress levels at capture due to being caught several times (Webb and Doroshov 2011). The catch per trip of boat anglers in the Columbia Gorge targeting white sturgeon ≥ 65 inches FL decreased from 0.28 fish in 2003, to 0.14 fish in 2004. In 2006, two years later, more post-spawn female white sturgeon were observed in research monitoring activities than in any of the previous six study years (Webb and Kappenman 2008). However, whether the catch per effort reduction is related to new regulations leading to a decrease in angler efficiency or to a decrease in broodstock abundance in this river reach is unknown (J. Watts, ODFW personal communication). Additionally, the effects of handling and release in commercial gillnet fisheries has not been fully assessed; however preliminary results of tests conducted by ODFW of white sturgeon 24-56 inches FL captured in commercial gill nets (2009 n=20, 2010 n=31) and held for 48 hours resulted in no observed mortality (Morgan 2011).

Incidental Hydrosystem Mortality

Operations at Bonneville Dam can result in the direct mortality of lower Columbia River white sturgeon. Mortalities mainly result from two specific operational events: Offline turbine units brought online and the dewatering of turbine draft tubes for scheduled and emergency maintenance. White sturgeon residing in draft tubes when turbine units are taken offline may perish when the unit is brought back online by being directly struck by rapidly moving turbine blades or by trauma caused by being rapidly expelled from the tube by high water velocities (B. Hausmann, USACE, personal communication). Offline turbines being brought online have resulted in fish kills of up to 80 individual fish at a time at Bonneville Dam (B. James, WDFW, personal communication; USACE, unpublished data), though fish kills of this magnitude are rare. Most events are much smaller (on the order of one to two fish killed) though they may happen each time units are brought online after being offline (B. Hausmann, USACE, personal communication). Operational changes to minimize white sturgeon mortality should include a slow ramping up of turbine operations; this practice is currently being used by the USACE at Bonneville Dam (B. Hausmann, USACE, personal communication).

White sturgeon may also suffer direct mortality at Bonneville Dam when turbine draft tubes are dewatered for scheduled maintenance or emergency repairs, which may lead to stranding related mortalities. In the past, isolated incidents of large fish kills, amounting to 500 – 2,100 white sturgeon during at least one incident were documented (B. James, WDFW, personal communication). However, current operational procedures, (i.e., rapid installation of tail logs post shut off, early visual inspection of dewatered draft tubes and re-location of any encountered fish) minimize mortality associated with this operational event (B. Hausmann, USACE, personal communication). Incidental hydrosystem mortality affects both spawning and rearing life stages. Though current operational procedures at Bonneville Dam have been established to minimize white sturgeon fish kills, some degree of direct mortality still exists. However, the actual magnitude of these events, especially the start-up of offline units which often occur at night, is currently unknown (B. Hausmann, USACE, personal communication).

Table 9. Summary limiting factors and which lower Columbia River white sturgeon life stages they impact. Factors are listed by type (Abiotic or Biotic), and the certainty and impacted life stages for each factor are indicated. Each factor is given a rating of high (Hi), medium (Med), or low (Lo) detailing the severity of the impact or the level of uncertainty surrounding the factor. An uncertainty rating of "Hi" indicates that we poorly understand the effects of this factor on the life stage and population. A "Lo" uncertainty rating would imply that the potential impact is well understood.

Factors	**Life Stage**				
	Uncertainty	**Spawning**	**Incubation**	**Dispersal**	**Rearing**
Biotic Factors					
Marine Mammal Predation	Hi	Hi	Lo	Lo	Med
Available Native Forage Species	Med	Med	Lo	Lo	Hi
Introduction of Non-Native Species	Med	Med	Med	Med	Med
Piscine Predation	Med	Lo	Hi	Hi	Med
Abiotic Factors					
Habitat Quality and Quantity	Med	Hi	Hi	Hi	Hi
Habitat Fragmentation	Med	Hi	Hi	Hi	Hi
Flow and Flow Variation	Lo	Hi	Hi	Hi	Med
Water Temperature	Med	Med	Hi	Med	Lo
Sediment	Hi	Lo	Med	Lo	Lo
Pollutants and Contaminants	Lo	Med	Med	Med	Med
Dissolved Gasses	Hi	Lo	Lo	Hi	Lo
Turbidity	Hi	Lo	Lo	Hi	Lo
Fishing Effects	Hi	Med	Lo	Lo	Med
Incidental Hydrosystem Mortality	Med	Med	Lo	Lo	Med
In-Water Work Effects	Med	Lo	Med	Med	Med

7.1.3 Plans, Objectives & Strategies

Primary co-managers for white sturgeon in this reach: *Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, Columbia River Inter-Tribal Fish Commission*

Lower Columbia River White Sturgeon Conservation Plan

ODFW has developed a Lower Columbia River White Sturgeon Conservation Plan (2011). WDFW staff was integrally involved in development of the plan and the Washington Fish and Wildlife Commission endorsed it. The conservation plan provides a framework to manage and conserve the species, ensuring a viable and productive population well into the future, while providing sustainable harvest opportunities and other societal benefits. The conservation plan is consistent with the Oregon Plan for Salmon and Watersheds, the Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan, and the Northwest Power and Conservation Council's Fish and Wildlife Program. It addresses the implementation of the Oregon Native Fish Conservation Policy by providing a basis for managing habitat, predators, and fisheries in balance with a sustainable, naturally producing white sturgeon population. ODFW developed the plan in collaboration with federal and tribal sturgeon researchers, state management partners, and the public. The plan is available at: http://www.dfw.state.or.us/fish/CRP/lower_columbia_white_sturgeon_plan.asp

The conservation plan lays out how ODFW will manage the Lower Columbia white sturgeon population segment to:

1. Avoid any substantial reductions in the population segment;
2. Maintain a naturally reproducing white sturgeon population segment in the lower Columbia River that makes full use of natural habitats, providing ecological, economic, and cultural benefits to Oregon residents; and
3. Provide sustainable commercial and recreational fishing opportunities.

7.1.4 Programs, Projects, Actions & Schedules

White sturgeon in the lower Columbia River population segment are currently monitored through a combination of fishery independent and dependent activities implemented by ODFW, WDFW, and Montana State University (MSU).

Population Monitoring

Fisheries independent activities include white sturgeon carcass surveys by WDFW, monitoring of the oversize population by researchers from MSU and WDFW field personnel, and monitoring of white sturgeon recruitment and stock assessments of the lower Columbia River white sturgeon population by ODFW staff.

Between June and September of each year, WDFW staff survey the Columbia River between RM 128 and RM 143 (B. James, WDFW, personal communication). When dead sturgeon are observed, they are counted and biological data (e.g., length, sex, maturity) are taken whenever possible. These observations are summarized and an informal report documenting sturgeon mortality is circulated to the Joint Columbia River Management Staff of ODFW and WDFW and to regional sturgeon experts and researchers.

From May to July each year, researchers from MSU and WDFW use set-lines to capture adult white sturgeon downstream of Bonneville Dam. They measure and tag the captured fish, determine the sex, and take a gonadal tissue sample for later laboratory examination (Webb and Kappenman 2008, 2009, 2010). The laboratory analysis allows for the reconstruction of reproductive structure and the documentation of spawning periodicity of the white sturgeon population.

In addition, since 2004 researchers from ODFW have used small mesh gill nets to document scope and magnitude of recruitment of white sturgeon in the lower Columbia River (Chapman and Weaver 2006). Gill nets are set at standardized indexing sites between RM 30–140 to capture age-0 white sturgeon. The captured white sturgeon are measured, and a pectoral fin spine section is removed for age verification and potential genetic analyses. Coupled with this recruitment work has been an examination by University of California at Davis, in collaboration with ODFW, of effective population size and genetic diversity of lower Columbia River white sturgeon from the 1940s, 1980s and 2000s. These tasks should enable, with time, the documentation of age-0 recruitment trends in the lower Columbia River; the relationship of recruitment to habitat conditions, broodstock abundance, and fishery regulations; and the description of the genetic diversity and effective female population size of lower Columbia River white sturgeon.

Abundance and exploitation rates of lower Columbia River white sturgeon are estimated annually (DeVore et al. 1999). During late spring/early summer, ODFW tags white sturgeon 35 inches TL with sequentially numbered "spaghetti" tags that are inserted at the base of the dorsal fin. Recaptures of tagged fish are generally obtained from sampling the lower Columbia River recreational and commercial fisheries. Occasional recaptures and tag returns from fishing effort outside the Columbia River system have been observed. A Petersen mark-recapture model for closed populations is used to estimate annual abundance of harvestable, legal-size white sturgeon each year (DeVore et al. 1999).

A pilot stock assessment of lower Columbia River white sturgeon was conducted in July-August 2009 (Jones 2009). This stock assessment was repeated, with modifications to sampling design to incorporate a random selection of sites and an increase in effort, in the summer of 2010. These assessments continue to improve our understanding of the size structure and condition of the lower Columbia white sturgeon population. They have provided a foundation for improving future population estimates of lower Columbia River white sturgeon. This effort, in conjunction with the previously mentioned tagging effort, produced the first within-year population estimate for the lower Columbia River in 2010 (Jones 2010). ODFW intends to use this newly adopted methodology in out years for estimating white sturgeon abundance in the lower Columbia River. The agency will continue to modify and refine the sampling following the tenets of adaptive management.

Fishery Monitoring

The commercial fishery in the lower Columbia River is monitored through a combination of mandatory landings reports from fish buying stations and field sampling activities to collect biological information. The goal of the monitoring activities are to determine the number and yield of the fishery by major commercial fishing zone.

A two-pronged approach is taken to accomplish this goal. Landings reports, called fish tickets, are produced when fishers deliver fish to buyers. The fish tickets include information on total fish weight and number of sturgeon delivered, and must be submitted to the respective management agency within five working days. Weight information from both Washington and Oregon landings is then combined to determine total yield. This method is considered more reliable than a total fish count because of the opposing interests of sellers and buyers in determining the total fish weight associated with a sale. To determine the number and location of the fish harvested, ODFW and WDFW field crews sample a minimum of 20 percent of the catch to collect biological information and recover tags. Each white sturgeon sampled is measured, weighed and examined for tags, tag scars, and missing scutes. Average weights are applied to the total landings to estimate the number of fish harvested.

Recreational fisheries in the lower Columbia River are monitored by seasonal creel surveys. Effort and catch estimates are generated for ten separate recreational sampling sections. At least six aerial counts per month (February through October) of boat and bank anglers in each section are used to estimate effort. Counts occur on randomly selected days, include at least one weekday, and one weekend day per week. During November, December, and January, estimates are generated from boat and ground-based sampling activities.

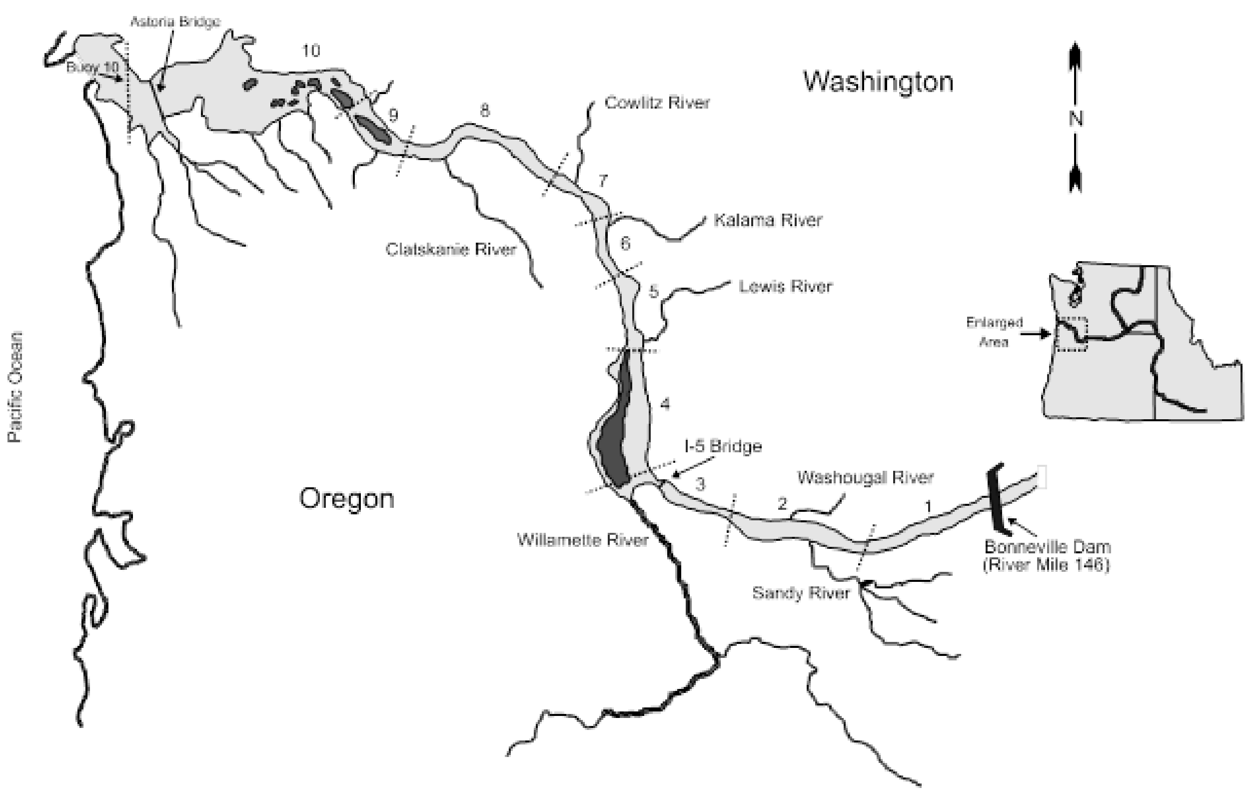


Figure 27. Recreational sampling sections of the Columbia River below Bonneville Dam.

Flow and Water Quality Monitoring

The Columbia Basin Water Management Division of the U.S. Army Corps of Engineers (USACE), Northwestern Division, is responsible for the USACE reservoir and mainstem regulation activities (primarily flood control and management of total dissolved gas) in the Columbia River Basin (USACE 2005). System-wide streamflow and hydropower project operations from headwater storage projects to below Bonneville Dam are monitored in-season by the Technical Management Team, which consists of federal, state, and tribal agencies, and is chaired by a USACE representative (USACE 2008). The team may recommend changes to specific hydropower project operations or system flow recommendations at regularly scheduled meetings, or at other times through System Operation Requests (SORs) made by team members or any other interested party. The Action Agencies (USACE, BPA and Bureau of Reclamation) have the final authority for implementation of any SOR. Team functions are intended, primarily, to oversee operations to benefit threatened or endangered Columbia River Basin salmon, steelhead, and bull trout, as well as white sturgeon; however, the needs of other aquatic species may also be considered (USACE 2008).

Water quality monitoring in the lower Columbia River Basin is conducted primarily by the Oregon Department of Environmental Quality (ODEQ) and the Washington Department of Ecology (WDOE) (Hallock 2008, Pickett and Harding 2002) for respective state water quality regulations and the federal Clean Water Act. Other water quality monitoring efforts in the lower Columbia River are conducted by the U.S. Environmental Protection Agency (EPA), the Oregon Department of Human Services, the City of Portland's Bureau of Environmental Services, Columbia Riverkeeper, and the U.S. Geological Survey (USGS).

In 1995, the USGS implemented the National Stream Quality Accounting Network (NASQAN) program to examine Columbia Basin water quality issues (Kelly and Hooper 1998). The primary objective of the Columbia Basin NASQAN is to provide a description of the concentrations and mass flux (the amount of material or load passing a given location per unit time) of sediment and chemicals at key locations, three of which are in the lower Columbia River (Kelly and Hooper 1998).

7.1.5 Needs & Uncertainties

ODFW (2011) identified a variety of critical unknowns and data gaps that could potentially impact the long-term conservation and viability of lower Columbia River white sturgeon:

- A large degree of uncertainty surrounds the abundance of white sturgeon in the lower Columbia River populations segment.
- The optimal abundance level for lower Columbia River adult white sturgeon is currently unknown.
- The actual distribution, abundance, habitat usage, relative proportion, and interchange of white sturgeon throughout those lower Columbia River waters downstream of Bonneville Dam is currently unknown.
- The stock composition of white sturgeon inhabiting those lower Columbia River waters downstream of Bonneville Dam is unknown.

- Impacts of global climate change remain unclear. Global climate change is likely to have a variety of effects on the lower Columbia River and the white sturgeon populations within.
- Although the probability that the lower Columbia River white sturgeon population will persist in perpetuity has recently been forecast, the model used to forecast it has not been through the peer-reviewed process.
- Declines from historic levels in white sturgeon native forage species (e.g., Pacific salmon species, Pacific lampreys, and eulachon) have been documented in the lower Columbia River and tributaries. Additionally, the status and abundance levels of native invertebrate populations, such as amphipods and mollusks, which were historically important food resources for white sturgeon, are unknown.
- Numerous intentional and unintentional species introductions have occurred in the lower Columbia River Basin, potentially affecting white sturgeon in a variety of ways.
- Total mortality of sub-adult and adult life stages of white sturgeon is composed of human and non-human sources of mortality. The extent of this mortality is not currently known.

7.2 Lower Mid-Columbia (Bonneville Dam to Priest Rapids Dam)

This management unit extends from Bonneville Dam to Priest Rapids Dam. The area contains Bonneville, The Dalles, John Day, and McNary reservoirs.

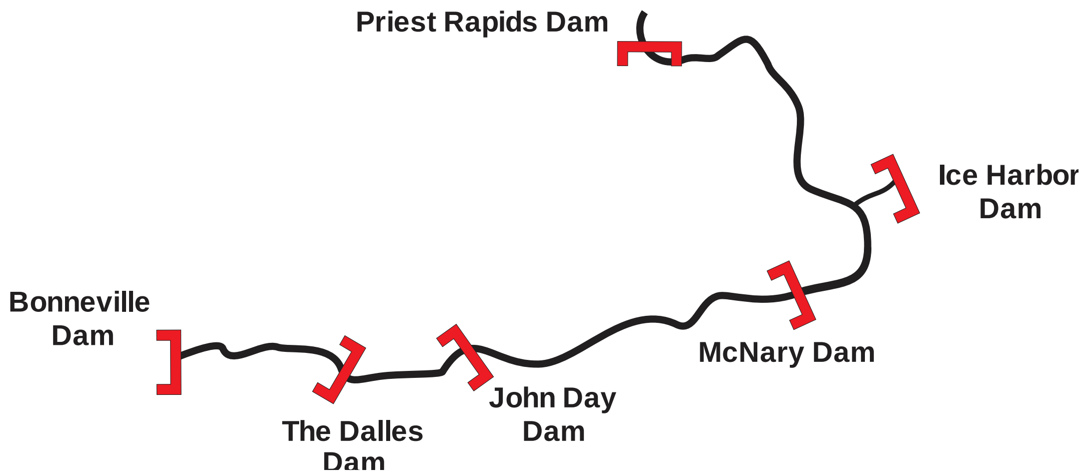


Figure 28. Map of the lower-mid-Columbia River sturgeon management unit.

7.2.1 Status

In the late 1980's white sturgeon populations in the Lower Mid-Columbia River were at relatively low levels of abundance. Beginning in 1988, substantial reductions to the sturgeon harvest quota, as well as specific harvest management actions designed to protect spawning-size fish (broodstock), have helped improve the status of these populations. Currently, most populations are at or near their highest abundance level since systematic monitoring began in the late 1980's. Recent abundance estimates for the white sturgeon populations of the Lower Mid-Columbia River are provided in the reservoir-specific subsections below.

Despite the relative improvement in status, these populations remain suppressed by high levels of recruitment variability as a result of dam construction and operation. Dam construction has blocked access to or inundated much of the historic spawning habitat, and constrained the movement of individuals to within a given impoundment. As a result, white sturgeon spawning activity in each of the impoundments is restricted to the area immediately downstream of a given dam, where dam discharge can create the high water velocities necessary for successful white sturgeon spawning (Parsley et al. 1993; McCabe and Tracy 1994). The amount of suitable spawning habitat has been correlated to the amount of discharge during the spawning cycle of white sturgeon (Parsley et al. 1993; Parsley and Beckman 1994). Unfortunately, spawning habitat is often limited (especially in low water years) as water is stored for flood control, power generation, irrigation and recreational use. The limited and variable nature of spawning habitat has created high levels of recruitment variability in most of these populations, with little to no measurable recruitment occurring in several years (see also *Flow and Flow Variation*, in Section 7.2.2).

Table 10. Abundance estimates for impounded lower Columbia River reservoirs and the Hanford Reach of McNary Reservoir, 1987–2010.

Year	30-72 inch total length N (95% CI)	24-36	36-48	48-60	60-72	72+	Sum	Number/ Acre[a]	Pounds/ Acre[c]
Hanford Reach and McNary Reservoir									
1995	5,234 (3,782-9,086)	900	2,700	3,400		1,250	8,250	0.2	8
Bonneville Reservoir									
1989	35,400 (27,500-45,400)	32,900	16,700	1,000	200	600	51,400	2.5	27
1994	35,200 (24,800-66,000)	31,300	18,300	1,300	200	900	52,000	2.5	--
1999	85,400[b]	82,400	41,800	3,200	600	400	128,400	6.2	59
2003	74,000[b]	84,500	33,000	1,100	120	780	119,500	5.7	46
2006	113,300	159,000	45,200	590	350	240	205,400	9.9	67
2009	235,713	223,955	106,086	3,112	3,749	1,064	334,424	16.1	149
The Dalles Reservoir									
1987	23,600 (15,700-33,600)	7,800	11,000	6,100	1,800	1,000	27,700	2.5	73
1988	9,000 (7,300-11,000)	4,200	4,300	1,500	500	800	11,300	1.0	32
1994	9,700 (7,500-14,000)	5,800	5,700	800	<50	300	12,600	1.1	--
2002	33,000 (26,200-42,000)	82,900	13,500	5,900	1,200	800	104,300	9.4	87
2005	45,700 (37,000-56,300)	90,600	10,200	1,100	500	400	102,800	9.3	69
2008	123,410[b]	55,600	74,800	1,650	200	950	133,200	12.0	132
John Day Reservoir									
1990	3,900 (2,300-6,100)	16,600	1,700	400	100	500	19,300	0.4	3
1996	27,100 (23,800-30,800)	5,800	19,700	4,050	350	700	30,600	0.6	11
2001	19,600[b]	14,900	12,800	1,100	300	900	30,000	0.6	9
2004	30,000[b]	30,200	11,500	1,100	170	470	43,500	0.8	9
2007	39,020[b]	17,834	21,793	1,587	529	841	42,584	0.8	10
2010	37,635[b]	4,472	29,110	3,900	718	2,449	40,649	0.8	14

Columns 24-36 through Sum: Number of fish by total length interval (inches).

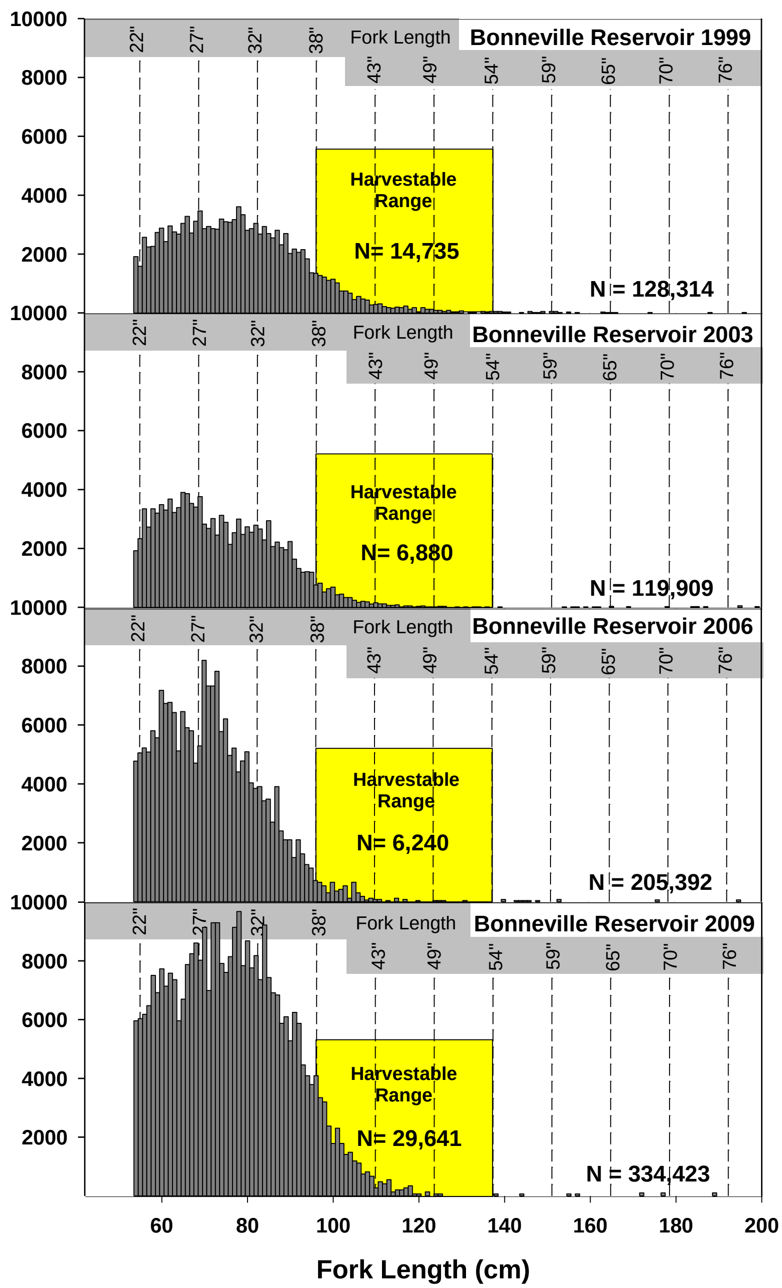
[a] Hanford Reach and McNary Reservoir = 45,500 acres; Bonneville Reservoir = 20,800 acres; The Dalles Reservoir = 11,100 acres; John Day Reservoir = 51,900 acres.
[b] Confidence intervals for these estimates are not provided because they are derived from expansion, not directly calculated from mark-recapture data.
[c] Total poundage is estimated by multiplying total abundance (40,649) by median weight (8.4 kg or 18.48 lbs) of sturgeon caught with setlines in sampling periods 2 and 3.

Table 11. Recruitment index values (E_P) for white sturgeon populations in Bonneville, The Dalles, John Day, and McNary reservoirs, 1997-2011. E_P= 0 is no measurable recruitment. E_P> 0 is measurable recruitment, with higher values equating to higher densities of age-0 sturgeon.

Year	Bonneville	The Dalles	John Day	Mc Nary
1997		0.74	0.53	
1998		0.73	0.08	
1999		0.67	0.22	0.08
2000		0.14	**0.00**	**0.00**
2001		**0.00**	**0.00**	**0.00**
2002		0.17	**0.00**	0.06
2003		**0.00**	**0.00**	**0.00**
2004		0.06	**0.00**	**0.00**
2005		0.03	**0.00**	0.03
2006	0.69	0.47	0.13	0.06
2007	0.31	0.14	**0.00**	0.06
2008	0.59	0.31	**0.00**	0.06
2009	0.51	0.42	0.13	0.06
2010	0.34	0.36	0.08	**0.00**
2011	0.41	0.61	0.46	0.26

Bonneville Reservoir

Bonneville Reservoir is bordered downstream by Bonneville Dam (Rkm 235) and upstream by The Dalles Dam (Rkm 308). Bonneville Reservoir is the lowest impounded reach on the Columbia River and has a surface area of 20,800 acres. The white sturgeon population in Bonneville Reservoir has increased substantially over the past decade (Figure 29). Currently, Bonneville Reservoir has both the highest abundance and density (16.1 sturgeon/acre) of white sturgeon (≥24 inches total length) in the Lower Mid-Columbia River. Age-0 indexing work in Bonneville Reservoir suggests that recruitment occurs each year, and is somewhat less variable than in the other impounded reaches.



in TL	Abund
24-35	79,312
36-47	44,589
48-59	3,447
60-71	620
72+	347

in TL	Abund
24-35	84,501
36-47	33,380
48-59	1,132
60-71	117
72+	779

in TL	Abund
24-35	166,887
36-47	37,315
48-59	592
60-71	355
72+	243

in TL	Abund
24-35	215,775
36-47	113,988
48-59	3,319
60-71	277
72+	1,064

Figure 29. Abundance estimates for white sturgeon (≥24 in total length) in Bonneville Reservoir, 1999-2009.

The Dalles Reservoir

The Dalles Reservoir is bordered downstream by The Dalles Dam (Rkm 308) and upstream by John Day Dam (Rkm 347). The Dalles Reservoir is the smallest reservoir in the Lower Mid-Columbia River, with a surface area of 11,100 acres. The abundance of white sturgeon in The Dalles Reservoir increased through 2008, before declining substantially in 2011 (Figure 30). The current density of white sturgeon (≥24 inches total length) is estimated at 9.1 sturgeon/acre. Age-0 indexing work in The Dalles Reservoir suggests that although recruitment occurs in most years (approximately 90% of the time), it is highly variable.

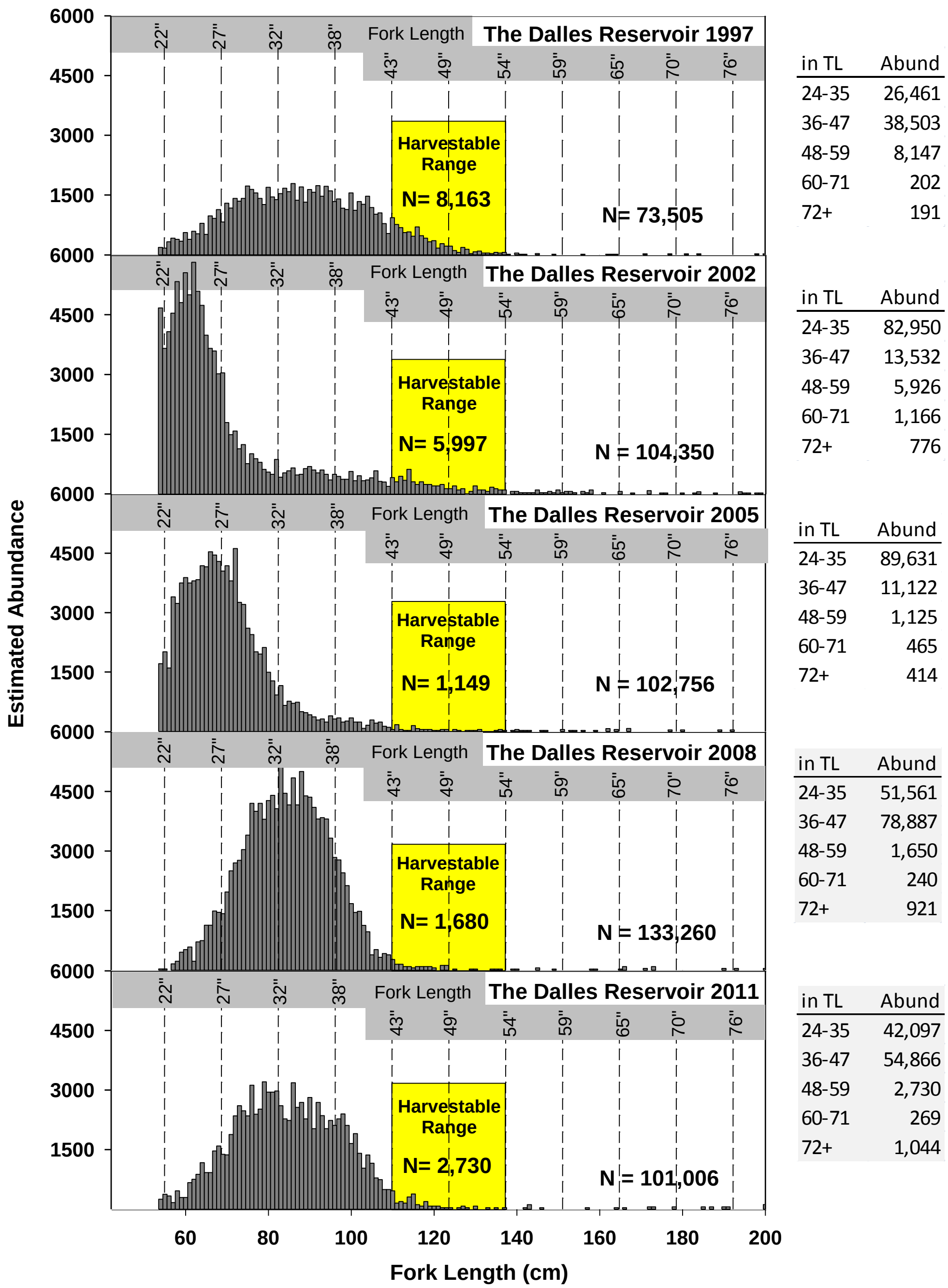
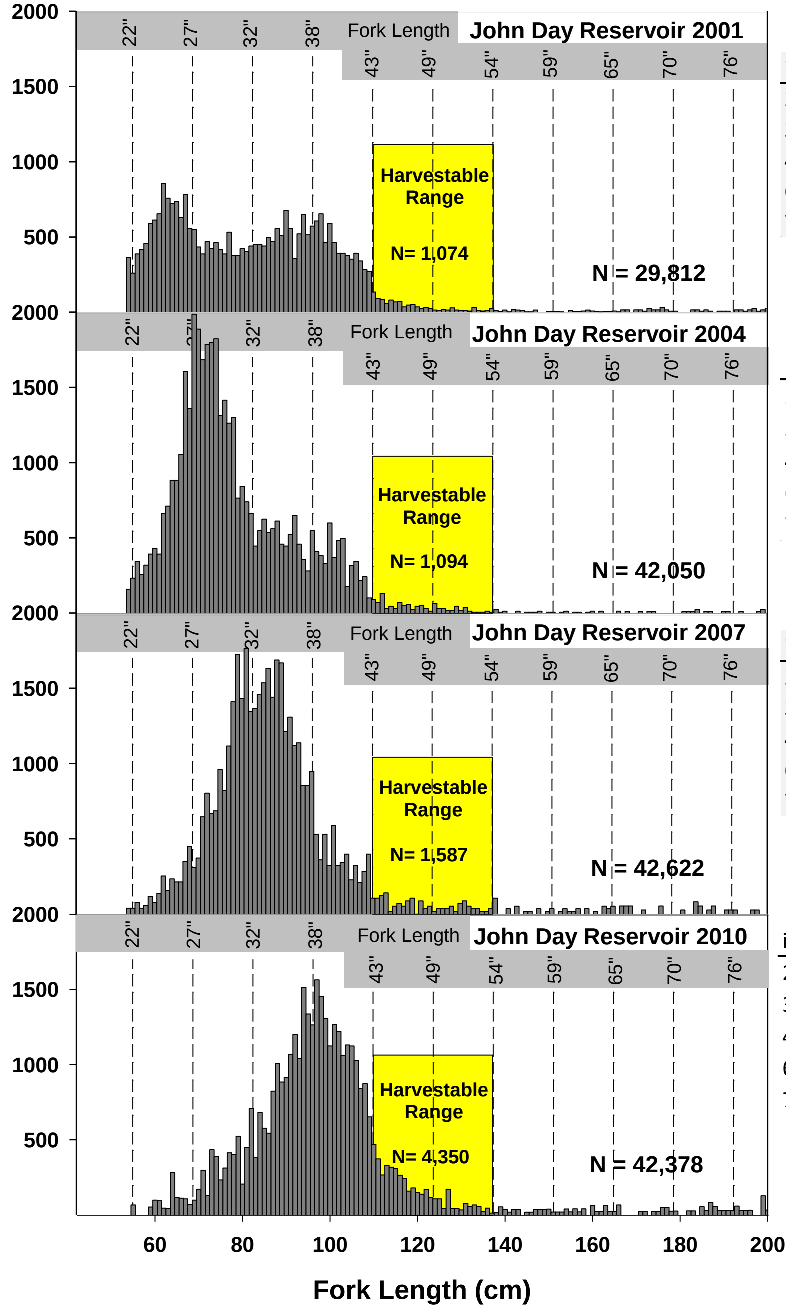


Figure 30. Abundance estimates for white sturgeon (≥24 in total length) in The Dalles Reservoir, 1997-2011.

John Day Reservoir

The John Day Reservoir is bordered downstream by John Day Dam (Rkm 347) and upstream by McNary Dam (Rkm 470). Although this reach is the largest in the Lower Mid-Columbia River (51,900 surface acres), the white sturgeon population is characterized by a relatively low abundance of older/larger individuals (Figure 31). The current density of white sturgeon (≥24 inches total length) is estimated at 0.78 sturgeon/acre. Age-0 indexing work in John Day Reservoir suggests that recruitment is generally poor, and occurs infrequently (less than 50% of the time). From 2000-2008 annual age-0 indexing captured only 5 age-0 fish (in 2006), suggesting nearly nine consecutive years of undetectable recruitment.



in TL	Abund
24-35	14,424
36-47	13,242
48-59	1,074
60-71	210
72+	862

in TL	Abund
24-35	28,280
36-47	12,185
48-59	1,094
60-71	171
72+	320

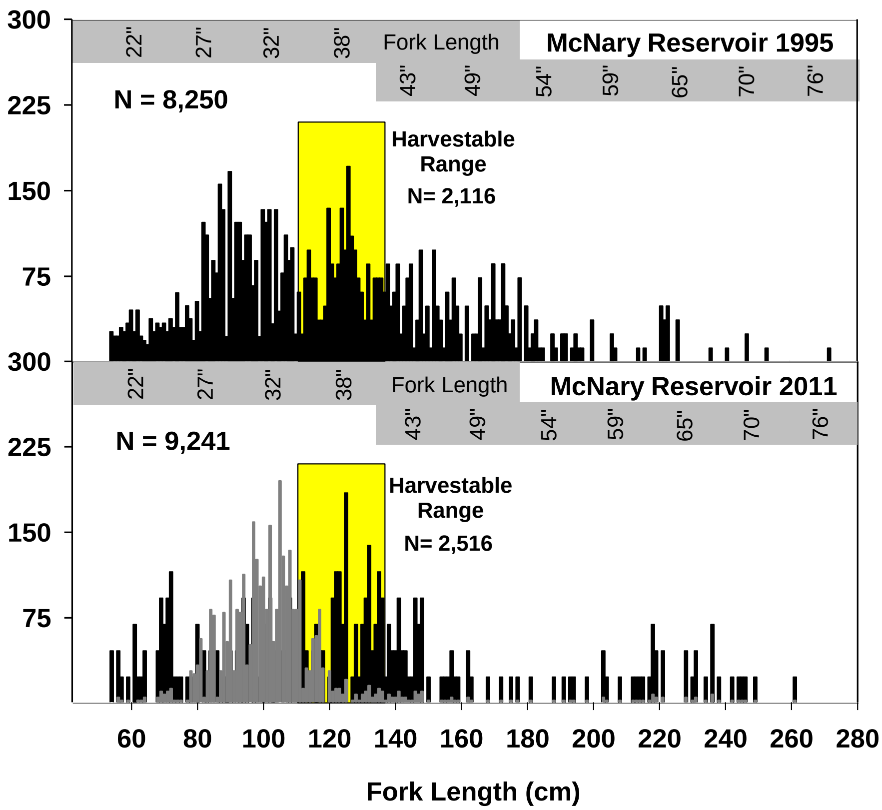
in TL	Abund
24-35	15,162
36-47	24,398
48-59	1,587
60-71	635
72+	841

in TL	Abund
24-35	5,132
36-47	28,594
48-59	4,350
60-71	809
72+	3,493

Figure 31. Abundance estimates for white sturgeon (≥24 in total length) in John Day Reservoir, 2001-2010.

McNary Reservoir (including the Hanford Reach)

McNary Reservoir is bordered downstream by McNary Dam (Rkm 470), upstream on the Columbia River by Priest Rapids Dam (Rkm 639), and upstream on the Snake River by Ice Harbor Dam (Rkm 16). Despite the relatively large size of this reservoir (45,500 surface acres), the white sturgeon population is characterized by a very low abundance of older/larger individuals. In 2011, the abundance of white sturgeon (≥24 inches total length) was 9,241 (0.20 sturgeon/acre). This estimate is similar to the previous estimate of 8,250 in 1995 (Figure 32). However, the population of white sturgeon in McNary Reservoir now contains an estimated 3,472 hatchery-reared white sturgeon which migrated downstream from their initial release location in Rock Island Reservoir (in 2003). The current population estimate, excluding hatchery-reared sturgeon, is 5,769 (0.13 sturgeon/acre). Age-0 indexing work in McNary Reservoir suggests that recruitment is generally poor, and occurs infrequently (less than 60% of the time). From 2000-2004 annual sampling for age-0 white sturgeon captured only 3 age-0 fish (in 2002), suggesting nearly five consecutive years of undetectable recruitment.



in TL	Abund
24-35	900
36-47	2,700
48-59	2,116
60-71	1,284
72+	1,250

in TL	Abund
24-35	1,168
36-47	3,478
48-59	2,516
60-71	1,001
72+	1,078

Figure 32. Estimated abundance of white sturgeon (≥ 24 inches total length) in McNary reservoir, 1995 and 2011. Grey bars in the bottom graph represent the estimated 3,472 hatchery-reared fish now part of the white sturgeon population in McNary Reservoir.

7.2.2 Limiting Factors & Threats

BIOTIC FACTORS

Predation: White sturgeon may be preyed upon both in freshwater and marine environments. Predation studies have documented that white sturgeon eggs and larvae, as well as young-of-year (age-0) white sturgeon are vulnerable to fish predators, including larger sturgeon (Miller and Beckman 1996; Gadomski and Parsley 2005b). Predation experiments indicated that predation on larval white sturgeon by predator fish was negatively correlated to levels of suspended sediments, suggesting that higher turbidities may make it more difficult for predators to locate and capture white sturgeon eggs, larvae and small juveniles (Gadomski and Parsley 2005a). Construction of the Federal Columbia River Power System (FCRPS) has decreased turbidity and potentially increased predation on white sturgeon eggs, larvae, and juveniles. Although a few studies have documented piscine predation on white sturgeon, the frequency and impact of this predation on white sturgeon at various life stages are poorly understood.

Abiotic Factors

Habitat fragmentation: Construction of hydroelectric dams in Lower Mid-Columbia River has fragmented the river habitat and created a series of functionally isolated white sturgeon populations (North et al. 1993, Parsley et al. 2007). Although fish passage structures are present at each of these mainstem dams, the structures were developed specifically for Pacific salmon and steelhead *Oncorhynchus spp.* and are generally not conducive to white sturgeon passage (Warren and Beckman 1993, North et al. 2002, Parsley et al. 2007). Functionally isolated by mainstem dams, each white sturgeon population in the Lower Mid-Columbia River must depend on conditions within a specific reach to sustain production. However, individual reaches do not contain optimal conditions for all life stages (Parsley and Beckman 1994).

Information regarding sturgeon population connectivity and movement past mainstem dams is limited in the Lower Mid-Columbia River basin. Long-term mark-recapture studies conducted by state agencies over the past two decades provide some indirect information regarding sturgeon movement past Lower Columbia River dams. Data from these studies showed that the majority (97%) of marked sturgeon were recaptured within the reservoir they were originally marked in, while 3% exhibited downstream movement, and less than 1% moved upstream (Hughes et al. 2006). In a four-year mark-recapture study of white sturgeon in the Lower Columbia River, North et al. (1993) noted that 27 (or 4%) of 635 recaptured white sturgeon migrated past a dam during the study. Of these, 26 moved downstream, and 1 moved upstream. The authors noted however, that the distribution of sampling efforts made observations of downstream movements more likely than upstream movements. Parsley et al. (2007) used a combination of acoustic and radio telemetry to examine passage of white sturgeon at The Dalles Dam from March 2004 through November 2005. The authors documented 26 passage events by 19 tagged fish; eight upstream via fish ladders and 18 downstream, mostly through open spill gates.

Results from these studies suggest a net downstream movement of white sturgeon within the Lower Columbia River. This unbalanced migration can have a negative effect on the genetic diversity of the population as a whole (Anders and Powell 2002, Jager et al. 2001). Jager et al

(2001) used a metapopulation model to examine the effects of habitat fragmentation on white sturgeon. Results showed populations with higher downstream than upstream migration rates were less likely to persist and lost more genetic diversity than populations with equal (upstream and downstream) migration. Results also showed that the likelihood of persistence decreased, and more genetic diversity was lost, as the rate of downstream migration increased. The authors noted that for white sturgeon the extinction risk associated with unbalanced migration outweighed the extinction risk associated with isolation (i.e. impoundment).

Habitat diversity, quality, and quantity: Construction of hydroelectric dams in Lower Mid-Columbia River has transformed the once dynamic, free-flowing river system into a series of homogeneous, reservoir-like habitats. Functionally isolated by mainstem dams, each white sturgeon population in the Lower Mid-Columbia River must therefore depend on conditions within a specific reach to sustain production. However, individual reaches may not contain optimal conditions for all life stages (Parsley and Beckman 1994). In some reaches suitable rearing habitat exists, but spawning habitat is limited and recruitment of fish is poor (Parsley and Beckman 1994). In other reaches, spawning conditions are favorable but growth of young fish may be density limited (Beamesderfer et al 1995).

Construction of the mainstem dams has also blocked access to and inundated historic spawning habitats throughout the Lower Mid-Columbia River. As such, the only areas known to provide suitable spawning habitat in the Lower Mid-Columbia River exist immediately downstream of mainstem dams, where dam discharge creates the high water velocities necessary for white sturgeon spawning (Parsley et al. 1993; McCabe and Tracy 1994). The area of suitable spawning habitat is known to be directly linked to the amount of spill at key times during the spawning cycle of white sturgeon (Parsley et al. 1993; Parsley and Beckman 1994). Reduced flows during spring and early summer (the spawning time of white sturgeon in the Columbia River basin) have been correlated to reduced recruitment of age-0 white sturgeon in the Lower Columbia River (Parsley and Beckman 1994).

Flow and flow variation: Prior to the construction of the Federal Columbia River Power System, Columbia River flows were characterized by high spring runoff from snowmelt and regular winter and spring floods. However, dam operations have reduced peak flows in spring and early summer, the spawning time for white sturgeon in the Lower Mid-Columbia River (Parsley et al. 1993, Quinn and Adams 1996, Quinn et al. 1997). Records demonstrate that post-FCRPS construction spring freshet flows have been reduced by more than 50% (Quinn and Adams 1996; Quinn et al. 1997; ODFW unpublished data), as water is stored for flood control, power generation, irrigation and recreational use. Similarly, winter flows have increased approximately 30% (Bottom et al. 2005). White sturgeon may have used the natural high flows during spring as a cue to initiate spawning (Parsley and Beckman 1994, Perrin et al. 2003). Additionally, increased flows during spring may have increased the survival of newly hatched larvae by decreasing predation (Gadomski and Parsley 2005) and aiding downriver dispersal to habitats favorable for growth (Parsley et al. 1993, Coutant 2004, van der Leeuw et al. 2006).

In the Lower Mid-Columbia River successful white sturgeon recruitment is influenced by available spawning habitat, which in turn is influenced by water velocity and water temperatures. That is, higher levels of discharge from the dams create the high quality spawning habitat necessary for successful spawning and recruitment. Data from age-0 indexing, combined with dam discharge data, suggest the relative density of age-0 white sturgeon is positively correlated to the amount of discharge from the dams during the spring and early summer; the spawning time for white sturgeon in the Lower Mid-Columbia (Figure 34; Chapman and Jones 2010; Parsley et al. 1993; Parsley and Beckman 1994). These data also support past findings that when discharge rates at McNary Dam reach or exceed 250 kcfs, there is generally a detectible level of recruitment in the reservoirs (Parsley 1993). Over the past 15 years of age-0 sampling, the only exception to this was in 2002 and 2008, when average discharge rates were greater than 250 kcfs and recruitment was not detectable in the John Day Reservoir (Figure 33; Chapman and Jones 2010).

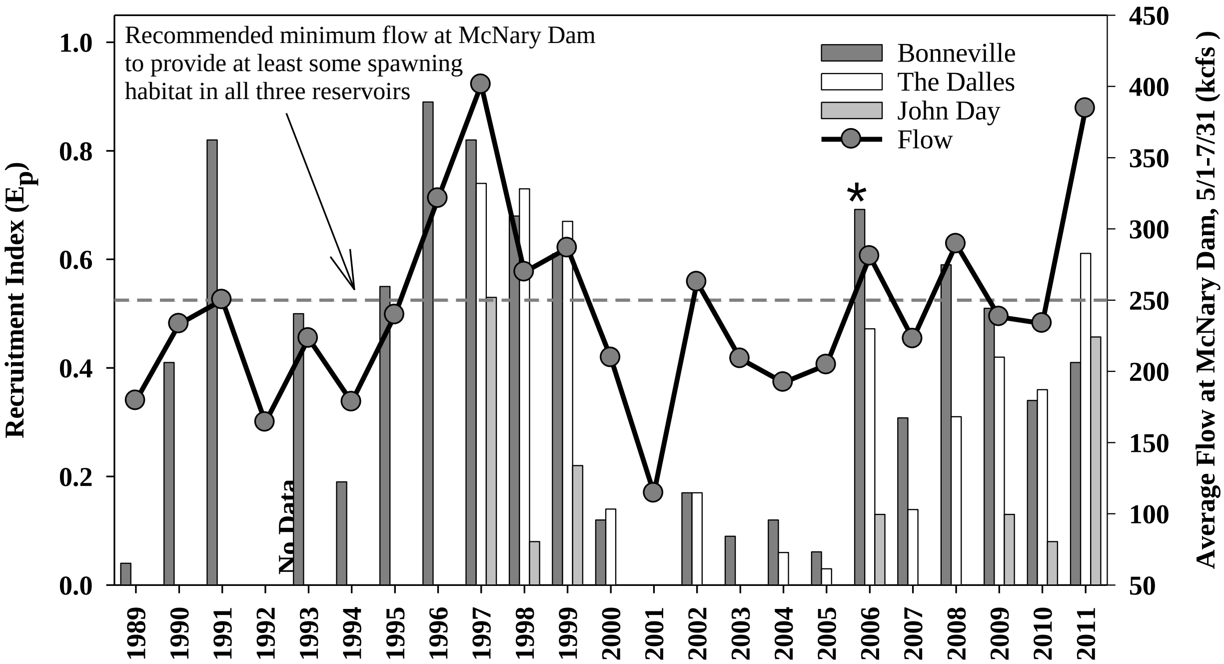


Figure 33. Recruitment index for white sturgeon in Bonneville, The Dalles, and John Day reservoirs, and average daily flow at McNary Dam (May-July). The dashed horizontal line indicates the recommended minimum flow to provide some spawning habitat in all three reservoirs.

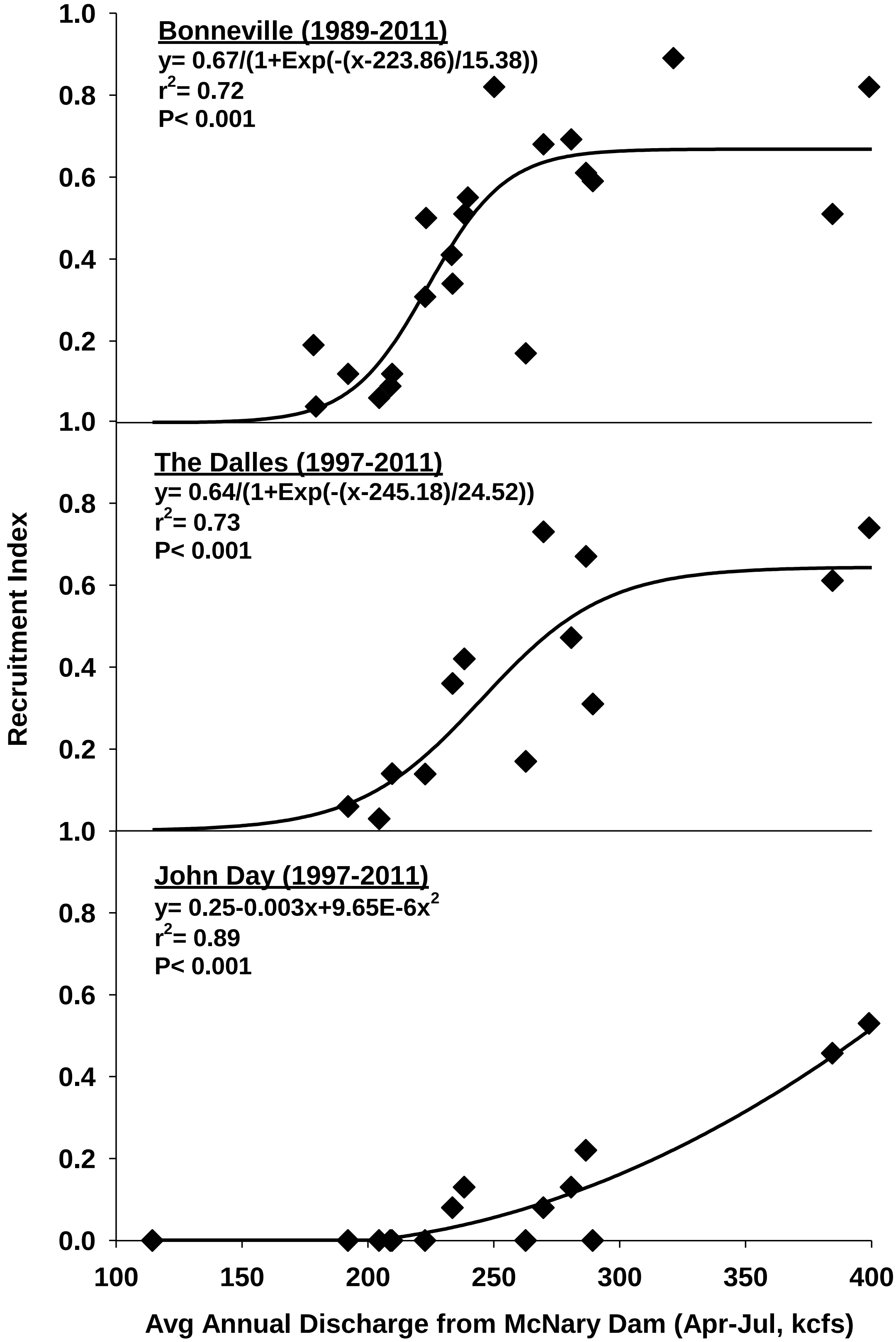


Figure 34. Relationship between annual recruitment index values and average discharge from McNary Dam (April-July) for Bonneville, The Dalles, and John Day reservoirs.

In addition to the alteration of the natural hydrograph, stream flow in the mainstem Columbia River can vary hourly and daily because of electrical load-following and power peaking (Kukukla and Jay 2003). Daily and hourly oscillations between high flow levels/tailwater elevations (during peak power generation) and low flow levels/tailwater elevations (during off-peak power generation) can occur, especially at low to moderate river discharges. This daily load-following cycle, and the ensuing changes in tailwater elevation, can result in substantial areas of riverbed being subject to a recurring watered-dewatered loop. In 2005 researchers from the U.S. Geological Survey (van der Leeuw et al. 2006) documented the presence of white sturgeon eggs and larvae in shallow water habitats on Ives Island downstream from Bonneville Dam. Of note, were 1-2 day post-hatch larvae collected at the upstream end of Ives Island. At the time of collection, the water-depth over the larvae was < 1.6 ft., and the larvae were found within the interstitial spaces among the cobbles comprising the riverbed. Larvae at this stage have low mobility (Brannon et al. 1985), and water surface elevation plots at Ives Island revealed that evening and early morning load-following operations may have dewatered the location where these larvae were found (van der Leeuw et al. 2006).

<u>Fisheries</u>: White sturgeon in the Lower Mid-Columbia River are subject to a variety of fisheries. As white sturgeon are removed via fisheries (before they reach sexual maturity), this effectively decreases the number of white sturgeon surviving to reach spawning size (i.e.broodstock). If the magnitude of established recreational and commercial fisheries were beyond sustainable levels, these legal fisheries could slow the growth of or reduce the size of this population. Because legal harvest is monitored and managed intensely, it is one of the few impacts that is easily quantifiable. Therefore, the impact of legal fisheries on the Lower Mid-Columbia River white sturgeon population is better understood than many other factors. It is important to note that the monitoring and careful regulation of legal harvest is the only limiting factor effectively addressed to date, and is solely responsible for the conservation and enhancement of the Lower Mid-Columbia River white sturgeon population.

In addition to the legal fisheries, illegal harvest (especially of broodstock) is a potential threat to white sturgeon populations. This is due to the high monetary value of spawning-size white sturgeon, specifically the eggs (or caviar) present in ripe females. The full extent of illegal harvest is difficult to measure. Currently, illegal harvest is monitored through the efforts of the Oregon State Police's Fish and Wildlife Division (OSP). In the Lower Columbia River, OSP reported 25 illegally harvested white sturgeon in 2008 and 48 in 2009. It is important to note that these are known illegal harvest numbers; the actual illegal harvest numbers are likely considerably higher. For example, in the mid-1990s a poaching ring based in Vancouver, Washington was exposed that had harvested approximately 2,000 adult sturgeon for 1.65 tons of caviar with an estimated value of $2,000,000 (Cohen 1997; Saffron 2002). In 2003, a white sturgeon poaching ring was apprehended with ties to both the Columbia and Sacramento rivers (Bailey 2003). If 2,000 adult white sturgeon were being removed annually in poaching related activities, this would account for approximately 10 – 15% of the current adult population (ODFW, unpublished data), and could be a limiting factor.

The stress associated with catch-and-release of adult white sturgeon (either targeted recreational catch-and-release fishing or release of fish incidentally encountered in pursuit of legal-size fish in *both* commercial and recreational fisheries) can negatively impact reproductive adults and thus population productivity, either through direct mortality or decreased reproductive success (Schreck 2010; Webb and Doroshov 2011). Recent research has found a strong positive correlation between the amount of time a fish is fighting on the end of a fishing line and stress hormones present in the blood, and that white sturgeon captured by hook and line had higher levels of stress hormones than those captured via set-line (Webb and Doroshov 2011). Although the cause of mortality is not definitive, and may not be associated with fishing, carcass surveys conducted by WDFW frequently find deceased white sturgeon with evidence of hooking injuries, such as open wounds in and around the mouth or fishing tackle trailing from either the mouth or the vent (WDFW, unpublished data).

There is no direct evidence linking the catch-and-release of over-legal size white sturgeon and reduced reproductive success; though correlative evidence suggests there could be a link (Webb and Doroshov 2011), and deleterious effects associated with catch-and-release angling have been demonstrated in other fish species (Schreck et al. 2001; Beggs et al. 1980). However, a lot of variability exists surrounding these relationships in Lower Columbia River white sturgeon – possibly because of multiple recaptures, i.e., even a fish that has been played for a relatively short time may have elevated stress levels at capture due to being caught several times (Webb and Doroshov 2011). The catch per trip of boat anglers in the Columbia Gorge targeting white sturgeon ≥ 65 inches FL decreased from 0.28 fish in 2003, to 0.14 fish in 2004. In 2006, two years later, more post-spawn female white sturgeon were observed in research monitoring activities than in any of the previous six study years (Webb and Kappenman 2008). However, whether the catch per effort reduction is related to new regulations leading to a decrease in angler efficiency or to a decrease in broodstock abundance in this river reach is unknown (J. Watts, ODFW personal communication). Additionally, the effects of handling and release in commercial gillnet fisheries has not been fully assessed. However, preliminary results of tests conducted by ODFW of white sturgeon 24-56 inches FL captured in commercial gill nets (2009 n=20, 2010 n=31) and held for 48 hours resulted in no observed mortality (Morgan 2011).

<u>Water Quality</u>:

Water Temperature- Water temperatures may act as a factor limiting white sturgeon spawning and recruitment. Peak spawning in the Lower Mid-Columbia River occurs at 55 to 59 °F (Parsley and Beckman 1994), though some may still occur at 64 to 66 °F (McCabe and Tracy 1994). Optimum water temperatures for the development of white sturgeon eggs and larvae are between 52 to 63 °F with negative impacts to larval development at temperatures above 63 °F (Wang et al. 1985).

Hydrosystem operations can cause unnatural and early increases in river water temperatures (Quinn and Adams 1996) to levels which can reduce the effective spawning habitat and are detrimental to developing white sturgeon eggs and larvae. Although FCRPS operations can and do affect the thermograph of the Lower Mid-Columbia River (Quinn and Adams 1996), it is currently unknown what effect this may have on the white sturgeon population.

Pollutants & Contaminants- Numerous contaminants have been detected in white sturgeon throughout the Columbia River Basin (Kruse 2000; Foster et al. 2001a and 2001b; EPA 2002). In general, contaminant concentrations are often highest near industrial or urban areas, but may be found throughout the Lower Mid-Columbia River mainstem as a result of transport and deposition mechanisms (NPCC 2004). White sturgeon may uptake contaminants through direct contact or bioaccumulation through the food chain.

The impounding of most Columbia River reaches has resulted in increased exposure of sturgeon to contaminants trapped in sediments behind the dams. Tissue samples (liver, gonad, and cheek muscle) from immature white sturgeon in the estuary, Bonneville, The Dalles, and John Day reservoirs have been collected and analyzed for chlorinated pesticides, PCBs, mercury and physiological, molecular, and biochemical measures of growth and reproductive physiology. The results suggest a link between contaminants and reduced growth and reproduction (Foster et al. 2001a, 2001b; Webb et al. 2006, Feist et al. 2005), and may affect all life stages of white sturgeon to some degree.

Our understanding of the exact effects that pollutants and contaminants have on white sturgeon is limited. Laboratory studies have shown some pollutants to be particularly toxic to white sturgeon and correlative evidence suggests that white sturgeon may be susceptible to bioaccumulation of environmental pollutants because of their life history characteristics (long-lived, late-maturing, benthic association, piscivorous at larger sizes; Foster et al. 2001a; 2001b; Feist et al. 2005; Webb et al. 2006). However, no direct link between pollutants and contaminants and abundance has been established yet.

Sediments- Deposition of fine sediments in the preferred spawning habitats can result in white sturgeon egg hypoxia, whereby eggs die from lack of oxygen. White sturgeon may suffer disproportionately from hypoxia compared to other fishes because of a limited ability to osmoregulate at low dissolved oxygen concentrations (NPCC 2004). Suspended sediments and various chemicals may also reduce the adhesiveness of newly fertilized eggs (Hanson et al. 1992). This adhesiveness allows the eggs to attach to the river bottom in areas of high water velocities needed for appropriate oxygenation during embryonic and larval development. Considering that white sturgeon prefer to spawn in turbid waters at high flows (Parsley et al. 1993; Perrin et al. 2003), it is unclear what effect fine sediments suspended in the water column might have on the reproductive success of white sturgeon.

Turbidity- Spring and summer turbidity levels in the Columbia River post-impoundment are lower than other unimpounded Pacific Northwest rivers (Gadomski et al. 2005a; Perrin et al. 2003). Construction of the FCRPS dams has contributed to decreased turbidity levels potentially increasing predation on white sturgeon eggs, larvae, and juveniles. Predation experiments have indicated that predation on larval white sturgeon by sculpin, a native piscivore, is negatively correlated to levels of suspended sediments, i.e., higher turbidities make it more difficult for predators to locate and capture white sturgeon larvae (Gadomski and Parsley 2005a). Although decreased turbidity in the Columbia River due to construction of the FCRPS likely increases predation related mortality for early life stages of white sturgeon, the actual magnitude and corresponding impact on the population is currently poorly understood.

<u>Direct hydrosystem mortality</u>: Operations at mainstem dams can result in the direct mortality of Lower Mid-Columbia River white sturgeon. Mortalities mainly result from two specific operational events: Offline turbine units being brought online and the dewatering of turbine

draft tubes for scheduled and emergency maintenance. White sturgeon residing in draft tubes when turbine units are taken offline may perish when the unit is brought back online by being directly struck by rapidly moving turbine blades or by trauma caused by being rapidly expelled from the tube by high water velocities (B. Hausmann, USACE, personal communication).

Offline turbines being brought online have resulted in fish kills of up to 80 individual fish at a time at Bonneville Dam (B. James, WDFW, personal communication; USACE, unpublished data), though fish kills of this magnitude are rare. Most events are much smaller (on the order of one to two fish killed) though they may happen each time units are brought online after being offline (B. Hausmann, USACE, personal communication). Operational changes to minimize white sturgeon mortality could include a slow ramping up of turbine operations; this practice is currently being used by the USACE at Bonneville Dam (B. Hausmann, USACE, personal communication).

White sturgeon may also suffer direct mortality at mainstem dams when turbine draft tubes are dewatered for scheduled maintenance or emergency repairs, which may lead to stranding related mortalities. In the past, isolated incidents of large fish kills, amounting to 500 – 2,100 white sturgeon during at least one incident were documented (B. James, WDFW, personal communication). However, current operational procedures, (i.e., rapid installation of tail logs post shut off, early visual inspection of dewatered draft tubes and re-location of any encountered fish) minimize mortality associated with this operational event (B. Hausmann, USACE, personal communication).

Though current operational procedures at most mainstem dam have been established to minimize white sturgeon fish kills, some degree of direct mortality still exists. The actual magnitude of these events, especially the start-up of offline units which often occur at night, is currently unknown (B. Hausmann, USACE, personal communication).

7.2.3 Plans, Objectives & Strategies

Primary co-managers for white sturgeon in this reach: *Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, Columbia River Inter-Tribal Fish Commission*

No overarching management plan currently exists for this management unit. However, a collaborative and comprehensive strategic planning for sturgeon conservation, restoration and management and including specific objectives, strategies, actions, milestones and schedules for habitat protection and restoration, natural production, hatchery production, fishery management, research, monitoring, and evaluation is being coordinated by CRITFC.

White sturgeon were selected as a focal species in the 2004 NPCC Subbasin Plan for the lower mid-Columbia mainstem. Objectives for white sturgeon include increasing abundance in the lower mid-Columbia mainstem (especially in reservoirs where the population is likely dying out). Corresponding strategies include: 1) continuing to develop hatchery technology and methodologies, 2) supplementing the sturgeon population in Priest Rapids Pool with hatchery fish, and 3) considering use hatchery fish to supplement The Dalles and John Day populations. The subbasin plan noted that hatchery technology has now progressed to the point where it may be possible to supplement white sturgeon populations in the lower mid-Columbia. In recent years, the development of more successful hatchery technology has resulted in a growing commercial aquaculture industry in California and the potential for further commercial and enhancement hatcheries in the Columbia River Basin (NPPC 2004).

7.2.4 Programs, Projects, Actions & Schedules

White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers Upstream from Bonneville Dam

An ongoing program is being implemented to manage and rebuild impounded white sturgeon populations in Bonneville, The Dalles, and John Day reservoirs. The program was designed to

- identify flows needed to provide significant recruitment,
- maintain viable natural spawning populations in each reservoir,
- optimize fisheries within the constraints of existing production, and
- rebuild populations and fisheries.

The program has included 1) indexing annual recruitment, 2) periodic stock assessment, 3) fishery monitoring, and 4) trap and transplant of juveniles from below Bonneville (NPCC 2004; Rien 2007; Mallette 2008). Unfortunately, the attempts to date have failed to restore significant levels of natural recruitment or opportunities for harvest (NPCC 2004; Mallette 2008; ODFW and WDFW 2008).

"Trawl and Haul" program

A "trawl and haul" program was implemented by the co-managers from 1994 to 2005. The objective was to determine the feasibility of using transplanted fish to 1) mitigate for lost recruitment and passage by directly increasing white sturgeon biomass in the impounded reach, 2) provide Treaty Indian harvest opportunities, and 3) improve the status of impounded white sturgeon populations by contributing individuals that would eventually recruit to the spawning population.

A total of 42,098 fish (30-90 cm FL, 1-6 years old) were transplanted from below Bonneville to The Dalles and John Day reservoirs between 1994 and 2005 (Rien 2006, 2007). The average annual survival rate was approximately 85% for each release group. The high survival rates of fish transplanted into The Dalles and John Day reservoirs were promising (Rien and North 2002), but the program was suspended after 2005 due to funding constraints, difficulties in capturing adequate numbers of fish below Bonneville, and concerns for impacts on the unimpounded population (Rien 2007).

Yakama Nation Sturgeon Management Project

The long-term goal of the Yakama Sturgeon Management Project is to facilitate restoration of viable populations and fisheries for white sturgeon in mid-Columbia River reservoirs. Phase I (2009-2010) of the Yakama Sturgeon Management Project (2008-455-00) will accomplish the following:

1) Assist in the development of a recovery, research and monitoring strategy, and hatchery Master Plan for depleted sturgeon populations in FCRPS portions of the mid-Columbia (below Priest Rapids Hydroelectric Project) and lower Snake rivers.
2) Continue to develop critical expertise and refine effective sturgeon culture methodology for spawning and rearing of white sturgeon using tribal staff, facilities and resources, and captive broodstock currently maintained on the Yakama Reservation at the Prosser and Marion Drain Hatcheries.
3) Identify facility and staff requirements and costs of hatchery alternatives for use in research/monitoring and hatchery Master Plan considerations (based on #2 and #3 above).
4) Develop a detailed implementation plan for production and rearing of juvenile sturgeon as appropriate for use in experimental research and hatchery feasibility evaluations (as identified in #1 above).
5) Assist in the development and implementation of effective experimental research and hatchery feasibility evaluations (as identified in #1 above).

Phase I of the Yakama sturgeon management project will provide critical input into the strategic and hatchery master planning process, help determine the potential suitability of tribal hatchery facilities for sturgeon, and facilitate implementation of appropriate hatchery-related measures identified in the strategic and master planning process.

7.2.5 Needs & Uncertainties

The following constraints and uncertainties need to be addressed for lower Mid-Columbia River white sturgeon:

- A large degree of uncertainty surrounds the abundance of white sturgeon in the lower Mid-Columbia River populations segment.
- Uncertainty regarding population dynamics and carrying capacity for each reservoir.

- Information is needed to determine critical habitat use by early life stages, and effects of environmental variables (including flow, flow variability, and contaminants) on year class strength.
- The actual distribution, abundance, habitat usage, relative proportion, and interchange of white sturgeon throughout the Columbia River between Bonneville and Priest Rapids Dams is currently unknown.
- Seasonal and diel habitat use by various life stages of white sturgeon remains unclear.
- Uncertainty in productivity– Annual growth, length-weight relationship, and relative weight of white sturgeon in Zone 6 reservoirs.
- Uncertainty regarding reservoir-specific genetic diversity, population differentiation, and gene flow.
- Uncertainty concerning how hydro operations (flow routing and load) influence spawning success (below the spillway, powerhouses, and transition zones); egg deposition; dispersal of free swimming embryos; and access to rearing habitats.
- Information needed on the loss of the historic prey base, and nutritional value of current pry base on population productivity.
- Uncertainty regarding potential benefits and risks associated with implementing a conservation aquaculture program.
- Uncertainty regarding the effects of upstream conservation aquaculture programs on white sturgeon in the lower Mid-Columbia reach.

7.3 UPPER MID-COLUMBIA (PRIEST RAPIDS DAM TO GRAND COULEE DAM)

The Upper Mid-Columbia management unit extends from Priest Rapids Dam upstream 200 miles to Grand Coulee Dam. This reach of the Columbia River contains Priest Rapids, Wanapum, Rock Island, Rocky Reach, and Wells Dams.

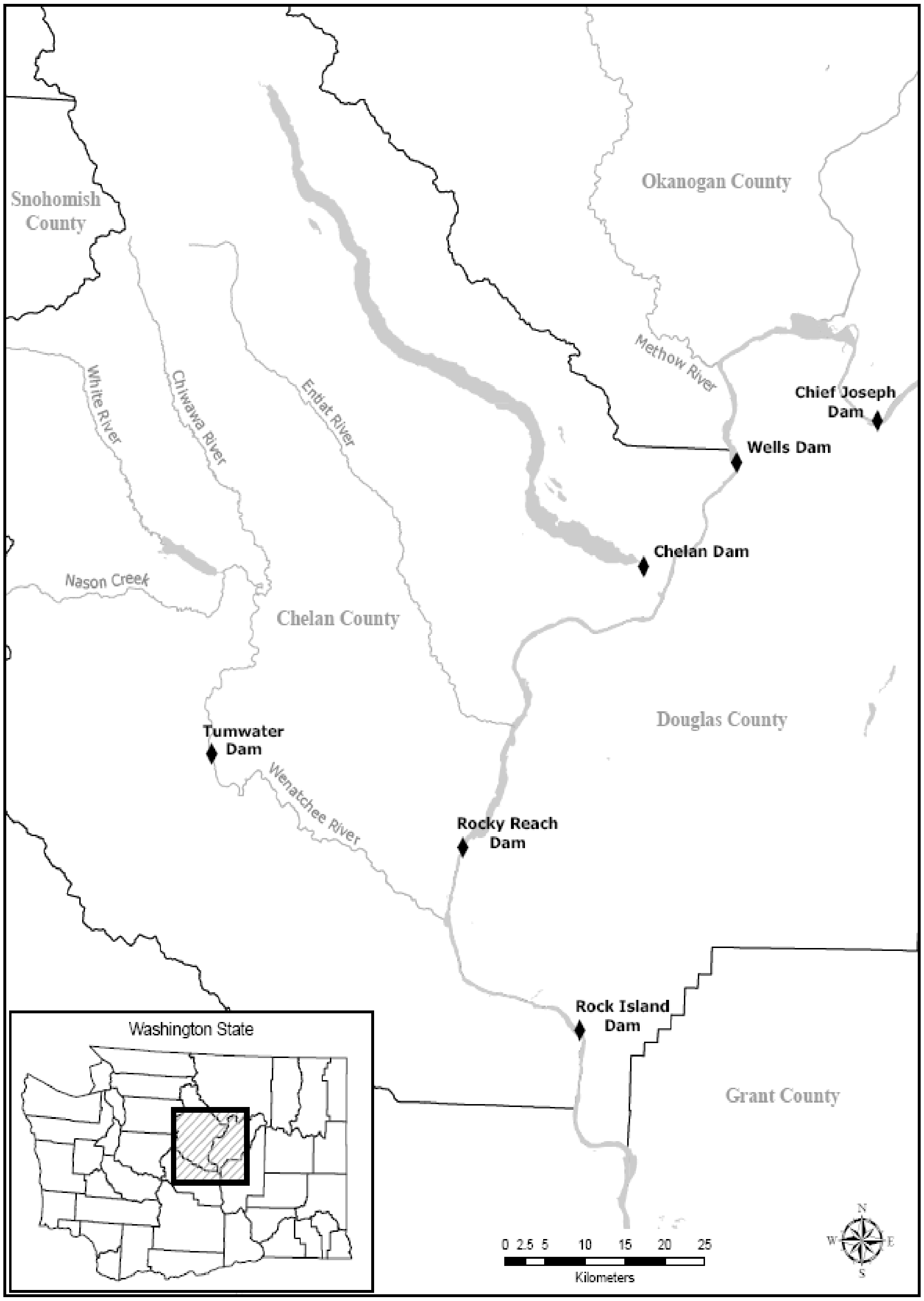


Figure 35. Map of the Upper Mid Columbia management unit, Priest Rapids Dam to Grand Coulee Dam (NPCC 2004).

7.3.1 Status

White sturgeon in the upper middle Columbia River exist as isolated subpopulations in the pools of hydroelectric projects with abundances around 50-500 individuals per pool, with approximately 500 sturgeon in Wanapum Reservoir, 130 in Priest Rapids Reservoir, and smaller populations in other reservoirs. The trend in these populations is declining or possibly stable at a low level. Spawning and/or recruitment success is minimal to nonexistent.

7.3.2 Limiting Factors & Threats

Habitat Fragmentation

White sturgeon in the middle and upper Columbia River reside in human-controlled and impounded reservoirs between dams. While construction of the dams along the middle reaches of the Columbia River has created "isolated" populations of white sturgeon, the population dynamics and factors regulating production of white sturgeon within these isolated populations remains poorly understood.

Sporadic or failing natural recruitment is characteristic of the impounded sturgeon populations. However, substantial uncertainties remain regarding our understanding of factors limiting sturgeon reproduction and recruitment. In contrast to the significant recruitment that occurs below Bonneville Dam, little recruitment is observed in the Upper Mid-Columbia reservoirs.

Habitat Diversity, Quality and Quantity

White sturgeon populations in this management unit are able to reproduce, however, the juvenile or larval fish have a very poor survival rate in the natural river, which leads to population declines. The potential effects of the hydroelectric projects on white sturgeon include river regulation, inundation of historical spawning and rearing habitats, impaired water quality, fish community changes, and population fragmentation.

Preliminary results from mobile tracking studies suggest that some juveniles produced from Lower Columbia captive broodstock and released into Wanapum and Priest Rapids reservoirs may actually leave the project areas. The reason for this outmigration is unknown. Some research suggests that the reservoir may not contain suitable rearing habitats for early life stages of white sturgeon, but they may be present downstream (GPUD 2008). Other studies have demonstrated that conditions in the reservoirs are favorable for juvenile growth and survival, but young sturgeon are being entrained or migrating to downstream reservoirs. In 2003, a substantial number of the 20,600 hatchery sturgeon released by CRITFC in Rock Island Reservoir were subsequently captured in downstream reservoirs as far as The Dalles, but primarily in other PUD reservoirs. Results from recent mobile tracking studies showed that Wanapum Pool had more downstream movement than Priest Rapids, but most of the fish stayed in the reservoirs.

Predation due to Changes in Fish Species Composition

The number of native and non-native predators has increased due to habitat alteration and the introduction of exotic species. Juvenile sturgeon are more vulnerable to predators because of reduced water turbidity resulting from construction of large upstream reservoirs.

7.3.3 Plans, Objectives & Strategies

Primary co-managers for white sturgeon in this reach: *Washington Department of Fish and Wildlife; Columbia River Inter-Tribal Fish Commission; Chelan, Grant, and Douglas Public Utility Districts*

Although no single comprehensive management plan currently exists for this management unit, white sturgeon are addressed in several area-specific plans as a result of FERC relicensing requirements. Chelan, Grant, and Douglas PUDs each white sturgeon management plans and initiated mitigation actions during their relicensing processes. Studies on white sturgeon life histories, distribution, and current population sizes provided the foundation for the development of appropriate management goals and objectives. The management plans were drafted in close coordination with agency and tribal natural resource managers. Members of the various working groups that assisted in plan development include: the USFWS, BLM, Washington Department of Ecology (WDOE), WDFW, CRITFC, the Confederated Tribes of the Colville Reservation (Colville), the Confederated Tribes and Bands of the Yakama Indian Nation, the PUDs, and other interested parties.

Priest Rapids Project White Sturgeon Management Plan

Grant County PUD completed the Priest Rapids Project White Sturgeon Management Plan in 2008 as part of the Priest Rapids project relicensing process. Biological objectives associated with this management plan consist of increasing white sturgeon populations to a level commensurate with available habitat through a supplementation program and the implementation of a monitoring program to determine population characteristics such as natural recruitment, spawning, rearing, growth, survival, and rates of emigration.

Specific biological objectives in the Priest Rapids Project White Sturgeon Management Plan include the following:

- Spawning and rearing in project area: Natural reproduction potential reached via natural recruitment.
- Spawning, rearing, and harvest in project reservoirs: Increase the white sturgeon population in Project reservoirs to a level commensurate with available habitat.
- Adult and juvenile upstream and downstream migration: Provide safe, effective, and timely volitional passage, if reasonable and feasible passage means are developed.
- Until reasonable and feasible means for reestablishing natural production and providing support for migration are available, and recognizing that those means appear unlikely in the foreseeable future, the biological objective is sustaining a population at a level commensurate with available habitat through implementation of a white sturgeon supplementation program in the project reservoirs. The supplementation program will provide an initial foundation for the monitoring and evaluation program, which is designed to a) identify existing impediments to achieving the biological objectives, b) sustain the populations until the existing impediments can be corrected, and c) mitigate for population losses due to project impacts.

The goal of this white sturgeon management plan is to 1) identify and address Priest Rapids project effects on white sturgeon and, 2) develop and implement "implementation measures" designed to avoid and mitigate for Project effects of white sturgeon. Adaptive management shall be applied to resolve critical uncertainties. In addition, the plan outlines the following tasks to achieve the biological objectives:

- Determine the effectiveness of the supplementation program in creating a sustainable white sturgeon population in the Project reservoirs based on natural production potential and adjust the supplementation program accordingly.
- Determine the carrying capacity of available white sturgeon habitat in each reservoir.
- Participate and cooperate in the development of any regional white sturgeon management effort initiated for the purpose of addressing flow fluctuation effects on the Hanford Reach white sturgeon population as a result of Project operations. If questions arise as to the appropriate level of participation and cooperation, Grant PUD shall request
- Determine juvenile downstream passage survival.

Rocky Reach White Sturgeon Management Plan

Chelan PUD completed a white sturgeon management plan in 2006 as part of the relicensing process for the Rocky Reach Hydroelectric Project. The overall goal of the Rocky Reach White Sturgeon Management Plan is to promote white sturgeon population growth in the Rocky Reach Reservoir to a level commensurate with available habitat. This is to be accomplished by meeting the following objectives:

1) Increase the population of white sturgeon in the Rocky Reach Reservoir through implementing a supplementation program.
2) Determine the effectiveness of a supplementation program in the Rocky Reach Reservoir.
3) Determine the carrying capacity of available habitat in the Rocky Reach Reservoir.
4) Determine natural reproduction potential in Rocky Reach Reservoir, and then adjusting the supplementation program accordingly.

White Sturgeon Management Plan for Wells Hydroelectric Project

Douglas County PUD is expected to receive a new FERC license in 2012 and will have similar requirement to Grant and Chelan Counties. The Wells Hydroelectric Project White Sturgeon Management Plan will direct implementation of measures to protect against, and mitigate for, potential Project impacts on white sturgeon. Specific objectives include:

- Supplement the white sturgeon population in order to address project effects, including impediments to migration and associated bottlenecks in spawning and recruitment.
- Determine the effectiveness of the supplementation activities through a monitoring and evaluation program.
- Determine the potential for natural reproduction in the Wells Reservoir in order to appropriately inform the scope of future supplementation activities.

- Adaptively manage the supplementation program as warranted by the monitoring results.
- Evaluate whether there is biological merit to providing safe and efficient adult upstream passage.
- Identify white sturgeon educational opportunities that coincide with WSMP activities.

7.3.4 Programs, Projects, Actions & Schedules

Sturgeon mitigation issues in upper mid-Columbia River reservoirs operated by the PUDs fall under the purview of FERC license requirements of Grant County PUD (Priest Rapids, Wanapum), Chelan County PUD (Rock Island, Rocky Reach), and Douglas County PUD (Wells). As part of the FERC relicensing agreements, the three mid Columbia PUDs are required to develop and implement protection, mitigation, and enhancement measures. The PUDs developed these measures in coordination with resource management agencies, tribes, and interested and affected parties.

Projects through Priest Rapids Project White Sturgeon Management Plan

A sturgeon hatchery is currently being constructed and is scheduled for completion in 2012. Hatchery production measures include:

- Annual broodstock collections starting in 2010
- Implement a white sturgeon supplementation program by releasing up to 6,500 yearling white sturgeon into the Wanapum reservoir each year, and 3,500 yearling white sturgeon into the Priest Rapids reservoir from 2011 to 2014, with subsequent annual release levels determined by the Priest Rapids Fish Forum based on monitoring results.
- Continue long-term index monitoring every five years over the term of the new license to monitor age-class structure, survival rates, and growth rates.
- Identify distribution and habitat selection of juvenile sturgeon.
- Direct the supplementation program strategy.
- Conduct tracking surveys of juvenile white sturgeon released with active tags as part of the supplementation program to determine emigration rates from Priest Rapids Project.
- Compile information on other white sturgeon supplementation programs in the region.

Projects through Rocky Reach White Sturgeon Management Plan

The Rocky Reach White Sturgeon Management Plan identified the following measures for protection, mitigation and enhancement of white surgeon populations.

- Prepare a broodstock collection plan within year one of the effective date of the new license and, if feasible, begin broodstock collection in year two of the new license.
- Implement a white sturgeon supplementation program by releasing up to 6,500 yearling white sturgeon into the reservoir each year for three years, with subsequent annual release levels determined by the Rocky Reach Fish Forum based on monitoring results.
- By year-seven of the new license, in consultation with the Rocky Reach Fish Forum, determine a long-term source of fish to be used for continuing the supplementation

program throughout the term of the new license.

- Conduct an initial three-year index monitoring program for juvenile and adult sturgeon in the reservoir to determine age-class structure, survival rates, abundance, density, condition factor, growth rates, and to identify distribution and habitat selection of juvenile sturgeon.
- Continue index monitoring every third year over the term of the new license to monitor age-class structure, survival rates, abundance, density, condition factor, growth rates; identify distribution and habitat selection of juvenile sturgeon; and direct the supplementation program strategy.
- Conduct tracking surveys of juvenile white sturgeon released with active tags as part of the supplementation program to determine emigration rates from the reservoir.
- Compile information on other white sturgeon supplementation programs in the region.
- Capture, insert active tags, and track reproductively viable adult white sturgeon for the purpose of identifying potential spawning locations, or, if no viable adult spawning white sturgeon are active-tagged as part of indexing program, place egg collection mats below Wells Dam to evaluate spawning activity and habitat utilization.

Projects through White Sturgeon Management Plan for Wells Hydroelectric Project

The plan identified the following measures for protection, mitigation and enhancement of white surgeon populations.

Phase I (Years 1-10)

- Develop a broodstock collection and breeding plan (Year 1 and updated as determined by the Aquatic Settlement Work Group).
- Collect broodstock (Years 1-4 and other years TBD by the Aquatic Settlement Work Group).
- Implement juvenile stocking program (Years 2-5 and other years TBD by the Aquatic Settlement Work Group).
- Conduct index monitoring program (Years 3-5 and 2 more years prior to Year 10 TBD by the Aquatic Settlement Work Group).
- Conduct marked fish tracking (Years 3-5 and 2 more years prior to Year 10 TBD by the Aquatic Settlement Work Group).
- Compile natural reproduction assessments (five annual assessments over license term).

Phase II (Years 11-50)

- Implement long-term juvenile stocking program (stocking rate and frequency TBD by Aquatic Settlement Work Group in Years 11-50).
- Conduct supplementation program review (Years 11-50 TBD by Aquatic Settlement Work Group).
- Conduct long-term index monitoring program (Year 12 and once every 3-5 years thereafter TBD by Aquatic Settlement Work Group).
- Prepare adult passage evaluation (Year 11 and once every 10 years thereafter).

Hatchery Supplementation Programs

In 2012, hatchery supplementation entered into a third year in the Priest Rapids and Rocky Reach project areas. To date, approximately 15,500 hatchery-origin juvenile sturgeon have been stocked in these two project areas. Hatchery fish from brood year 2011 are currently being held at the Yakama Nation Marion Drain White Sturgeon Hatchery (GPUD's fish) and WDFW Chelan Hatchery (CPUD's fish). Reduced stocking levels are planned for 2012 (500-1,000 fish range) due to the low number of brood stock collected in 2011. The 2012 brood stocking plans for Grant PUD and Chelan PUD are essentially the same as 2011, with hopes of increasing effort and collecting fish from the John Day Pool. White surgeon monitoring and evaluation activities continue in the Priest Rapids project area and are scheduled to begin in 2012 in the Rocky Reach project area. Douglas County PUD is evaluating proposals to initiate their hatchery supplementation program in 2012.

7.3.5 Needs & Uncertainties

The following challenges and uncertainties need to be addressed for the Upper Mid-Columbia white sturgeon management unit:

- It remains unclear whether the supplementation programs can effectively create a sustainable white sturgeon population in the reservoirs based on natural production potential. Potential broodstock limitations and constrains need to be evaluated.
- More information is needed on population dynamics and the carrying capacity of available white sturgeon habitat in each reservoir.
- Information is needed to evaluate the loss of the historic prey base, and the nutritional value of the current prey base on population productivity.
- Uncertainty regarding adequacy of coordination between mid-Columbia white sturgeon activities and related activities by downstream managers.

7.4 Transboundary Upper Columbia (Grand Coulee Dam to Hugh L. Keenleyside Dam)

This management unit crosses the U.S./Canada border, extending from Grand Coulee Dam to Hugh L. Keenleyside Dam. The reach supports a white sturgeon subpopulation that largely resides in the free-flowing transboundary reach that contains Lake Roosevelt.

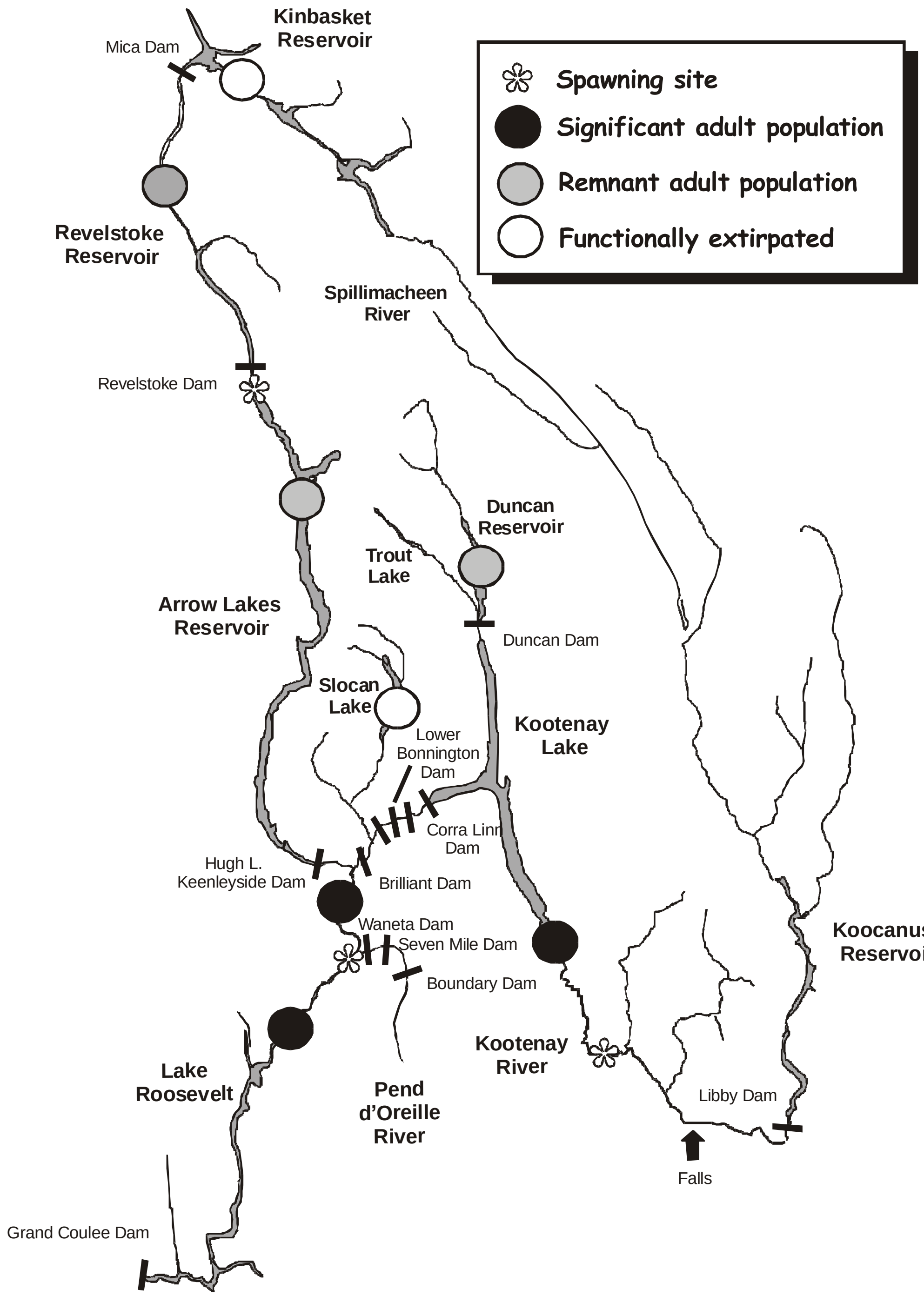


Figure 36. The Transboundary Upper Columbia River Management Unit.

7.4.1 Status

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 percent within 10 years, and 75 percent within 20 years.

The Canadian population 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 Keenleyside Dam and Lake Roosevelt. White sturgeon in the 56 km section of the Columbia River between Keenleyside Dam 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 Keenleyside Dam, 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 one year of catch and catch per unit effort 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. The reported size distribution of white sturgeon in Roosevelt Lake is similarly dominated by adult fish.

Table 12. 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 lat July	Pend d'Orelle-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			
Larval	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
Young-of-the-year	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
Younger juveniles	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
Older juveniles	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.
Adult Feeding	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 reflects 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

7.4.2 Limiting Factors & Threats

Habitat Fragmentation

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). The area still supports many big sturgeon, but natural recruitment is very low.

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).

Flow Regulation

Flow regulation has likely contributed to poor spawning and early-rearing success of white sturgeon in the upper Columbia River. Increased storage in the upper basin and hydro system operation have generally eliminated floods, reduced spring flows, and increased late summer through winter discharges (UCWSRI 2002). 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. [need area-specific]

Water Quality

<u>Temperature</u>

Downstream of Keenleyside Dam, average fall and winter temperatures are similar but temperatures from May through September are 2-3º C warmer than occurred historically. 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. 24º 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.

<u>Contaminants</u>

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. These compounds are potentially bioavailable to fish and other aquatic fauna.

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.

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.

Habitat Diversity, Quality and Quantity

The historic riverine habitat structure in the reach 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 due to flood control and flow regulation are more subtle but no less significant. Historical floods helped maintain channel diversity by periodically scouring and rearranging materials to create pool and backwater habitats. The 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 that may be used directly by sturgeon or by important food sources.

Increased Predation due to 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 primary changes have been the elimination of anadromous species and an increase in introduced species. At the same time, juvenile sturgeon are more vulnerable to the introduced species due to the reduction in water turbidity that followed construction of the large upstream reservoirs.

The current fish community of the mainstem Columbia River between Keenleyside Dam and Lake Roosevelt is dominated by mountain whitefish, rainbow trout, northern pikeminnow, and suckers. Whitefish are very abundant. Kokanee are also common, with most likely entrained from Arrow Lake but a few also originating in Lake Roosevelt. In Lake Roosevelt, introduced species such as walleye and smallmouth bass, as well as kokanee salmon dominate the current fish community. Coastal rainbow trout, brook trout, and brown trout also occupy the lake, but native salmonids, such as bull trout, westslope cutthroat trout, and redband trout are rarely encountered. The mountain whitefish populations have been replaced by lake whitefish.

7.4.3 Plans, Objectives & Strategies

Primary co-managers for white sturgeon in this reach: *Washington Department of Fish and Wildlife, Spokane Tribe of Indians, Colville Confederated Tribes, Canadian Columbia River Inter-Tribal Fish Commission, Canada Dept. of Fisheries and Oceans*

Upper Columbia White Sturgeon Recovery Plan

The Upper Columbia White Sturgeon Recovery Plan, developed by the Upper Columbia White Salmon Recovery Initiative (UCWSRI) in 2002, is the product of a cooperative effort by Canadian and U.S. governmental aboriginal, industrial and environmental organizations, stewardship groups, and citizens.[1] A recovery team included technical representatives from federal, provincial, and state resource management agencies, and 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 plan is available at: http://www.llbc.leg.bc.ca/public/pubdocs/bcdocs/362040/recovery_vol1.pdf.

The recovery plan describes objectives, targets, strategies, measures, and a schedule for stopping the decline of white sturgeon in Canadian and U.S. portions of the Columbia River upstream from Grand Coulee Dam; ensuring the persistence and viability of naturally reproducing populations; and restoring 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 range extends from Grand Coulee Dam upstream to the Columbia River headwaters, excluding the Kootenay drainage downstream of Lower Bonnington Dam.

Short-, medium-, and 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, potentially expensive effort. The short-term objective (within 5 years) 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 (within 10 years) is to determine survival limitations (bottlenecks) for remaining supportable populations and establish feasible response measures to reduce or eliminate limitations. The long-term objective (within 50 years) is to re-establish natural population age structure, target abundance levels, and beneficial uses through self-sustaining recruitment in two or more recovery areas.

Initial efforts focus on recovery areas within the historic geographic range that continue to provide suitable habitat. Potential recovery areas include the upper transboundary reach from Keenleyside Dam to the international boundary, the lower transboundary reach from the

[1] *A revised recovery plan was recently been made available by the Upper Columbia White Sturgeon Recovery initiative (Hildebrand and Parsley 2013) but has not yet been incorporated into this section.*

boundary to Grand Coulee Dam, and Arrow Lakes Reservoir (Revelstoke Dam to Keenleyside 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 that 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.

7.4.4 Programs, Projects, Actions & Schedules

Upper Columbia White Sturgeon Recovery Initiative

The Upper Columbia White Sturgeon Recovery Initiative has implemented a suite of research, monitoring and evaluation and production activities, which include (UCWSRI 2006):

- Sturgeon fish culture operations at British Columbia and Washington facilities
- Broodstock collection and tagging activities
- Transboundary reach juvenile monitoring
- Communications, public outreach and education efforts
- Contaminants and fin deformity investigations
- Adult sturgeon monitoring in Lake Roosevelt and Lake Waneta
- Stock assessment and telemetry studies in the transboundary reach
- Geomorphologic and population sub-structure analyses
- Temperature effects on incubation success and survival
- Technical and community working groups advisory and administrative support
- Annual public reporting through a public workshop

Early on, the UCWSRI determined that fish culture was a key element in the conservation and restoration of upper Columbia white sturgeon. The Freshwater Fisheries Society of British Columbia was enlisted to operate the fish culture facilities since they already had experience through their work with the Kootenai Tribe of Idaho (culturing Kootenai River white sturgeon stock in BC as part of the Tribe's fail-safe program).

A pilot hatchery program for upper Columbia white sturgeon was initiated with the modification of a provincial trout hatchery (Hill-Mackenzie Creek Hatchery) located at Galena

Bay (UCWSRI 2008). Broodstock collection and spawning began in 2001 and juveniles were first released in 2002 (UCWSRI 2008). In 2003, the program was transferred to the larger Kootenay Sturgeon Conservation Hatchery near Cranbrook, British Columbia. A pilot U.S. hatchery program was also begun at Moses Lake, Washington in February 2004 with Canadian 2003 brood juveniles for release in 2004. The U.S. program began collecting its own broodstock in 2006 (UCWSRI 2008).

Through 2007, 92,818 hatchery-raised juvenile white sturgeon representing 44 families were released between Keenleyside and Lake Roosevelt (UCWSRI 2008). Since 2005, Canadian releases have included both fall (sub-yearling) and spring (yearling) release groups. Releases in the U.S. portion of the transboundary reach have occurred each year since 2004. Releases at Revelstoke were first made in 2007 (UCWSRI 2008). Production in the U.S. began in 2006.

Initial UCWSRI hatchery production targets were based on population targets and assumptions identified in the 2002 Recovery Plan (UCWSRI 2002). Monitoring of initial release groups has recently provided empirical estimates of hatchery survival and condition following release (UCWSRI 2008). Recent evaluations conducted as part of the Canadian listing under SARA also included a Recovery Potential Assessment, which modeled recovery trajectories based on assumed survival rates (UCWSRI 2008).

In 2008, the UCWSRI initiated a comprehensive review of the upper Columbia white sturgeon recruitment failure hypothesis (Gregory and Graham 2008). Ultimately, this review resulted in the prioritization of research, monitoring and evaluation, hatchery, and mitigation actions associated with specific prioritized recruitment failure hypotheses. The UCWSRI is currently working on merging the results of the 2008 recruitment failure hypotheses with revisions to their current five-year work plan. In addition, the recently completed national draft White Sturgeon Recovery Strategy, once finalized, is likely to provide additional guidance that the TWG will have to consider in their mitigation programs, monitoring and evaluation program and hatchery release targets.

The following schedule describes a list of activities for implementation consistent with the goals and objectives of the Upper Columbia White Sturgeon Recovery Plan. Actual implementation schedules will be contingent upon the resources available for plan implementation.

<u>Short Term (within 5 years)</u>

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.

   1b. Identify and reduce sources of direct dam and other industrial related mortality.

2. *Increase early life stage survival through improved water and habitat management*

   2a. Initiate adaptive water storage/release management plan within recovery areas.

2b. Initiate water quality improvement plan within recovery areas (temperature, turbidity, and total gas pressure).

2c. Initiate habitat restoration plan and undertake select habitat improvements (minimum of 1 project/recovery area).

2d. Initiate studies to clarify the sources and level of predation mortality.

2e. Identify sources and impacts of predation mortality.

2f. Initiate investigations of contaminant effects on sturgeon.

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.

3b. Provide adequate numbers of cultured juvenile sturgeon to support research plans.

3c. Investigate feasibility of experimental culture/fail safe hatchery facility for U.S. portion of the transboundary recovery area.

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.

<u>Medium Term (within 10 years)</u>

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.

1b. Research plan completed and recruitment limitations identified for each recovery areas.

1c. Minimize significant sources of direct dam and other industrial related mortality.

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

2a. Complete preliminary adaptive water management experiments within recovery areas.

2b. Complete feasible water quality improvements within recovery areas.

2c. Complete feasible habitat improvements for each recovery area.

2d. If predation is identified as a potential bottleneck, implement measures to reduce predation, which could include habitat improvements.

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.

   3b. Maintain pilot conservation culture operations to meet conservation targets (increase population to minimum sustainable levels while maintaining genetic diversity) within recovery areas.

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

   4a. Maintain monitoring program to track habitat conditions and population structure within recovery areas.

   4b. Monitor indices (juvenile abundance) which demonstrate significant probability of population persistence throughout geographic range.

<u>Long Term (within 50 years)</u>

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.

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.

   2b. Provide an average rate of recruitment that exceeds that required for population replacement.

   2c. Ensure adequate sexually mature adults are present to meet conservation targets within recovery areas.

   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.

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.

3b. Implement fail-safe population(s) program (assume 1 fail-safe population in Canada and 1 in the USA).

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

5a. Maintain monitoring program to track habitat conditions and population structure within recovery areas.

5b. Monitor indices (juvenile abundance) which demonstrate significant probability of population persistence throughout geographic range.

Lake Roosevelt Sturgeon Recovery Project

The Lake Roosevelt Sturgeon Recovery Project began in 2003 as a cooperative effort between the Spokane Tribe of Indians, Washington Department of Fish and Wildlife, and Colville Confederated Tribes with funding by BPA. The project has three components: 1) status and trend monitoring, 2) recruitment failure research, and 3) conservation aquaculture.

The program has changed in recent years to address genetic and practical concerns with using transboundary wild-caught broodstock utilized in conservation aquaculture. Concerns included the limited numbers of broodstock used, no initial monitoring and evaluation, declining ability to collect broodstock over time due to growth/mortality, impacts on natural spawning stock, and potential effects on efforts to restore natural recruitment. The parties have now implemented an alternative approach, collecting naturally produced larvae, based on the success of early life history studies. Large catches of larvae indicated that sturgeon were spawning and incubating successfully, but not surviving beyond the stage when they began exogenous feeding. The benefits of using larval collection rather than adult broodstock include increased effective population size, decreased relatedness, reduction in artificial selection pressures, imprinting, and decreased stress/mortality effects on the broodstock population. Potential drawbacks to larval collection include hatchery infrastructure modifications (for the Lake Roosevelt project specifically), disease concerns, more labor intensive from both field collection and husbandry perspectives, and size at release. The release objective is 4,000 larvae per year in the US portion of the transboundary reach. Currently, presumed genetic benefits (increased numbers of spawners and decreased relatedness) are under study. The wild broodstock collection effort has been suspended.

7.4.5 Needs & Uncertainties

The following challenges and uncertainties need to be addressed for the Transboundary Upper Columbia white sturgeon management unit:

- More information is needed to determine the abundance levels and carrying capacity of available white sturgeon habitat in each reservoir.

- Researchers are collecting a lot of data, but lack the staff resources to analyze it. This makes it difficult to evaluate the success of the various approaches. Many of the samples collected for genetic analysis have not been analyzed.
- Cryopreservation of milt has not worked yet, but there is a Norwegian company looking into it.

7.5 Headwaters Upper Columbia (Keenleyside Dam to Kinbasket Reservoir)

The Far Upper Columbia management unit covers the Canadian reach of the Columbia River that extends from Keenleyside Dam to Kinbasket Reservoir. The reach includes Arrow Lakes Reservoir, and Revelstoke and Mica Dams.

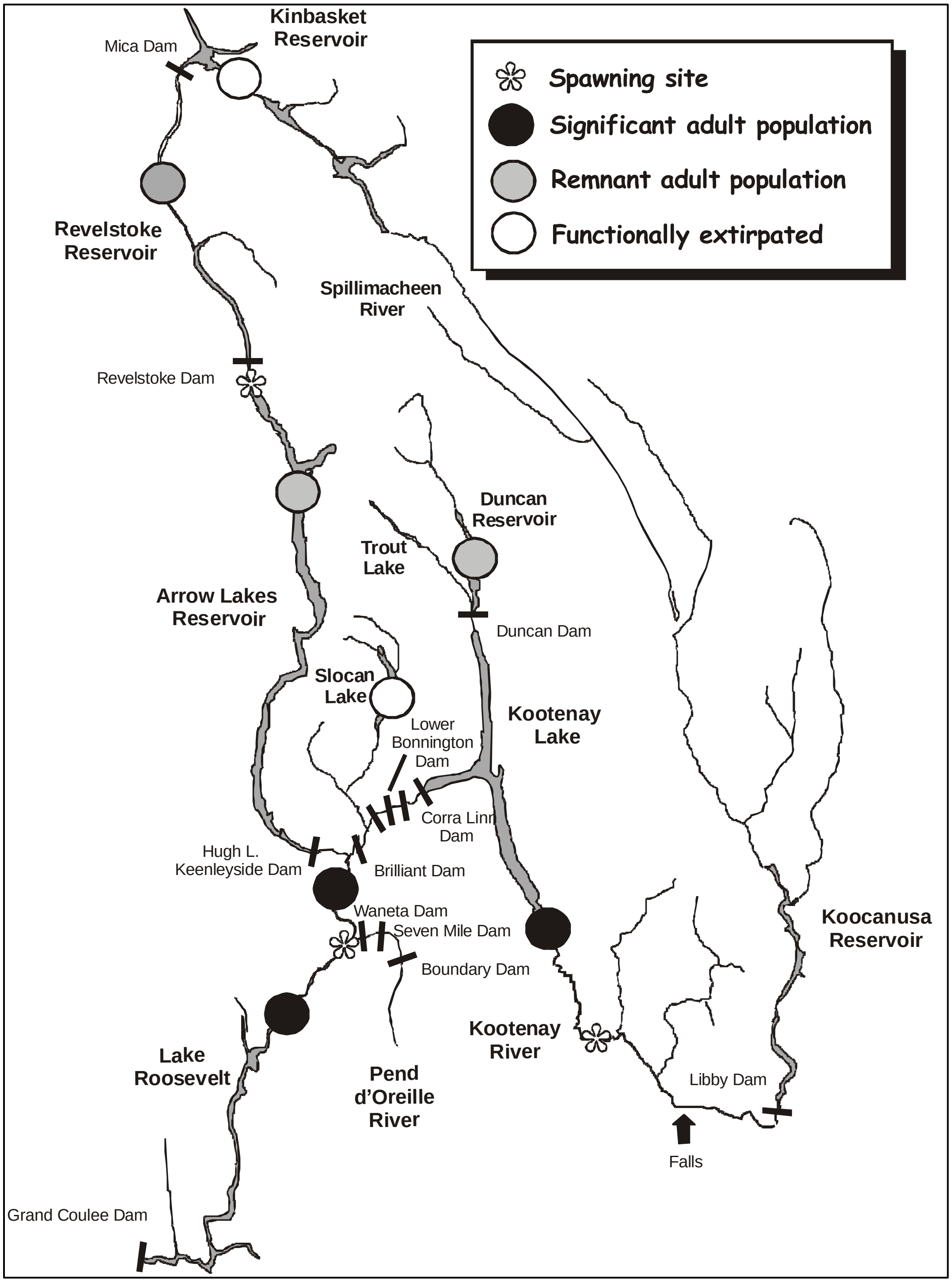


Figure 37. Headwaters Upper Columbia River Management Unit.

7.5.1 Status

Without immediate, aggressive, and effective intervention, the far upper Columbia white sturgeon population is expected to decline below critical thresholds from which recovery may be difficult. 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 far upper Columbia River is projected to decline to less than 500 adults within 14 years. It is expected to become functionally extinct around the year 2044 as numbers fall below 50 fish.

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 far upper Columbia River sturgeon belies a notion that their longevity provides an extended opportunity for implementation of this recovery plan.

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 of the sturgeon 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 Arrow Lake Reservoir fish are all large subadults or adults. One spawning event was documented near Revelstoke in 1999 but the absence of younger fish in the Arrow Lake Reservoir population indicates a failure of natural recruitment (RL&L 2000b).

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).

7.5.2 Limiting Factors & Threats

Habitat Fragmentation

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. Keenleyside, 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 Keenleyside 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.

Flows and Flow Variation

Flow regulation has likely contributed to poor spawning and early-rearing success of white sturgeon in the upper Columbia River. Increased storage in the upper basin and hydro system operation have generally eliminated floods, reduced spring flows, and increased late summer through winter discharges.

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.

Water Quality

<u>Temperature</u>

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.

<u>Dissolved Gases</u>

Dam construction and operation has increased dissolved gas to supersaturation levels downstream from several facilities including Mica, Revelstoke, Keenleyside, Waneta, and Brilliant Dams. 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 percent. Since 1977, the Columbia River below Keenleyside Dam was identified as having the highest TGP concentrations of the 35 major rivers or lakes examined in B.C. (Clark 1977).

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. These compounds are potentially bioavailable to fish and other aquatic fauna.

Nutrients

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.

Habitat Diversity, Quality and Quantity

The historic riverine habitat structure in the reach 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 due to flood control and flow regulation are more subtle but no less significant. The 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).

Predation and Competition due to changes in Fish Species Composition

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, redside 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.

7.5.3 Plans, Objectives & Strategies

Primary co-managers for white sturgeon in this reach: *Canadian Columbia River Inter-Tribal Fish Commission, Canada Dept. of Fisheries and Oceans, B.C. Hydro, Canada Ministry of Water, Land and Air Protection*

Upper Columbia White Sturgeon Recovery Plan

The Upper Columbia White Sturgeon Recovery Plan, developed by the Upper Columbia White Salmon Recovery Initiative (UCWSRI) in 2002, is the product of a cooperative effort by Canadian and U.S. governmental aboriginal, industrial and environmental organizations, stewardship groups, and citizens. The recovery plan describes objectives, targets, strategies, measures, and a schedule for stopping the decline of white sturgeon in Canadian and U.S. portions of the Columbia River upstream from Grand Coulee Dam; ensuring the persistence and viability of naturally reproducing populations; and restoring 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 range extends from Grand Coulee Dam upstream to the Columbia River headwaters, excluding the Kootenay drainage downstream of Lower Bonnington Dam. Section 7.4.3 describes this plan.

7.5.4 Programs, Projects, Actions & Schedules

Upper Columbia White Sturgeon Recovery Initiative

The Upper Columbia White Sturgeon Recovery Initiative continues to implement a suite of research, monitoring and evaluation and production activities directed through the Upper Columbia White Sturgeon Recovery Plan (UCWSRI 2006). Section 7.4.4. summarizes programs, actions and schedules associated with the initiative to improve white sturgeon populations.

7.5.5 Needs & Uncertainties

Challenges and uncertainties specific to the Far Upper Columbia white sturgeon management unit have not been identified.

7.6 Kootenay Lake & Kootenai River

The Kootenai River (spelled Kootenay in Canada) originates in the Kootenay National Park, British Columbia, and flows through Montana and Idaho before joining the upper Columbia River in British Columbia. White sturgeon range from Kootenay Lake upstream 237 km to Kootenai Falls but are primarily found in the 120 km low gradient reach downstream from Bonners Ferry, Idaho and in the lake.

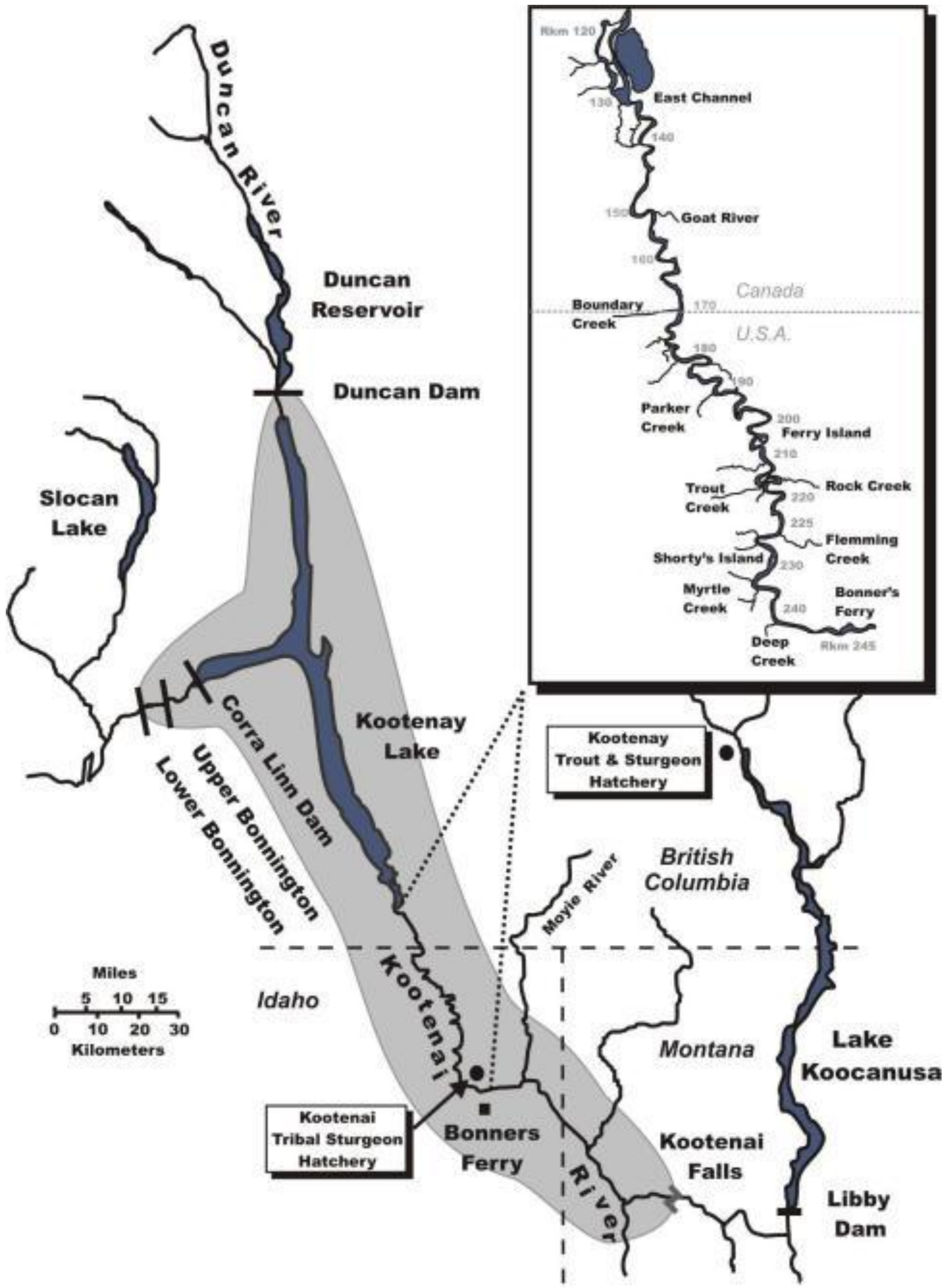


Figure 38. The Kootenay Lake/Kootenai River Management Unit.

The Kootenai River supports the only naturally landlocked white sturgeon population in North America. Kootenai sturgeon have been isolated by a natural barrier at Bonnington Falls downstream of Kootenay Lake since the last glacial age approximately 10,000 years ago (Alden 1953, Northcote 1973). In the interim, this population has adapted to specific local conditions in this headwater system. Kootenai white sturgeon are active at cooler temperatures (Paragamian and Kruse 2001), spawn in different habitats and colder temperatures (Paragamian et al. 2001), and have lower genetic diversity than other populations in the Sacramento, Columbia, and Fraser systems (Bartley et al. 1985; Setter 1989; Setter and Brannon 1992; Anders et al. 2000; Anders et al. 2002; Anders and Powell 2002; Rodzen et al. 2004).

7.6.1 Status

The Kootenai white sturgeon population was listed as endangered in the U.S. under the ESA in 1994 and in British Columbia under SARA (the Canadian federal Species at Risk Act) in 2006 (USFWS 1994). Kootenai River white sturgeon have been declining for at least 50 years and extinction of the wild population now appears imminent (Paragamian et al. 2005). An estimated 991 wild adults (95% CI: 914-1,074) remained in 2009 (Beamesderfer et al. 2013). There has been little or no annual natural recruitment since 1974, corresponding with closure of Libby Dam, though natural recruitment was depressed and/or absent prior to 1974. The apparent causes of this decline are spawning over low quality sand-silt substrates and loss of ecosystem function (riparian, diking, floodplain connection, food web) (Duke et al. 1999; USFWS 199; Anders et al. 2002; KTOI and MFWP 2004). Numbers have already reached critical low levels where genetic and demographic risks are acute. Without intervention, functional extinction would occur well before the last wild fish dies (KTOI 1997).

7.6.2 Limiting Factors & Threats

Floodplain Habitat and Connectivity

Physical habitat conditions in the lower Kootenai River floodplain have been altered by loss of off-channel connectivity and conversion of natural wetland and riparian habitats to agricultural production. Attempts to dike the lower river began in the late 1800s (Northcote 1973). By 1931, nine drainage/diking districts had constructed an extensive series of levees, drainage ditches, and pumping stations to reclaim 22,000 acres of land (Pick 1991). By 1990, over 90 percent of the historical floodplain habitat was separated from the river by levees. The loss of flooded riparian vegetation likely reduced the availability of critical incubation and early rearing habitat (Coutant 2004). Paul: Add whole large river-floodplain ecology stuff here.

Flows and Flow Variation

Flow regulations affected sturgeon spawning and early rearing conditions (Paragamian et al. 2001). Construction of Libby Dam and Koocanusa Reservoir in 1972 and subsequent operations for power production have drastically altered water flow patterns, temperatures, and water quality in the Kootenai River (Duke et al. 1999; Paragamian and Kruse 2001). Average annual peaks in the lower river during spring declined from 60,000 kcfs to 20,000 kcfs after Libby Dam construction. Average winter flows and water temperatures were increased by reservoir releases for power generation. Flood volumes and frequencies are also much reduced.

In addition, Kootenay Lake elevation has been regulated by operations at Cora Linn Dam at Bonnington Falls near the lake's outlet, which was completed in 1932 and allowed to begin impounding Kootenay Lake following an IJC order in 1938. Kootenay Lake is situated in the Purcell Trench, formed by ice age glaciers. Prior to dam construction, spring runoff would typically raise the lake level by about 9 feet and the lake would back up into the Kootenai River valley and affect upstream river hydrology. Since dam construction, runoff continues to increase the lake level by 3 meters, but the lake starts at a lower level after a late winter draw down to avoid spring flooding.

The complex effects of reduced flood flows and reduced Kootenay Lake elevations, as well as levee construction, have altered the location of the gradient transition zone where sturgeon spawn. These changes have also altered substrate conditions throughout this area of the river. Current spawning predominantly occurs downstream from Bonners Ferry in an 18 km section of the upper meander reach, which is largely a sediment depositional zone where mobile underwater sand dunes and fine sediments can cover and suffocate eggs (Barton 2004; Kock et al. 2006). White sturgeon spawning occurs annually in this reach; however, near total mortality also occurs prior to completion of the embryo stage (Anders et al. 2002; Rust et al. 2010, 2011?)

Water Quality

The thermal regime of the Kootenai River has also been affected by Libby Dam operations. In the post-dam era, Libby Dam operations have generally increased median Kootenai River temperatures by more than 5°F (2.8°C) during the winter months, increased by about 2°F (1°C) on the rising limb of the spring freshet, and reduced the summer median temperatures by about 2°F (1°C) until the fall. (Figure). A manual gate system allowing selective vertical withdrawal options was implemented in 1977 to better control the temperature of water released from Libby Dam.

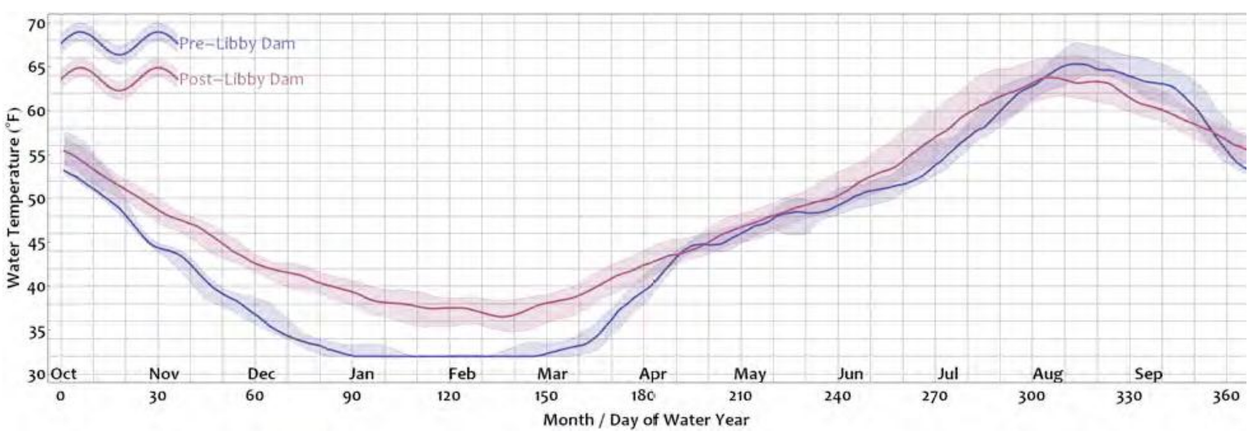


Figure 39. Pre and post dam water temperatures for the Kootenai River at Porthill (USGS Station # 12322000) (Figure 3.2. from the Kootenai River habitat Project Master Plan (KTOI 2009).

Nutrients

Kootenay Lake was originally mesotrophic (nutrient moderate), but became eutrophic (nutrient rich) due to effluent discharges and then oligotrophic (nutrient poor) following pollution abatement and upstream reservoir construction. However, nutrient levels were artificially elevated from the 1950s through 1970 by discharges from pulp mills, municipal effluent, and a fertilizer plant on the St. Mary River in British Columbia (Northcote 1973). Pollution abatement and fertilizer plant closure reduced phosphorus loading to the system by one or two orders of magnitude (Daley et al. 1981, Ashley and Thompson 1993, Ashley et al. 1994, 1997; Ahrens and Korman 2002). Lake Koocanusa acts as a nutrient and sediment sink (Daley et al. 1981, Woods 1982, Snyder and Minshall 1996).

Habitat Diversity, Quality and Quantity

Ecosystem conditions along the Kootenai were altered through diking, diversions, and conversion of floodplains habitats that resulted in the loss of riparian, slough and side channel habitat. Portions of the Kootenai watershed have been heavily logged or mined with significant effects on aquatic habitats throughout the system (Northcote 1973; Loern 1976; Daley et al. 1981). Watershed changes have altered annual flood and base flow discharges from tributaries and increased sedimentation. Mining activities along with industrial effluents have introduced contaminants into the system.

The lack of suitable spawning and incubation substrate in current spawning areas is thought to be a primary factor limiting sturgeon recruitment. Sturgeon eggs and embryos have been consistently collected from deep high-velocity parts of the river channel near Shorty's Island. However, it is assumed that shifting sand dunes in that reach may cover and suffocate eggs, delaying hatch and reducing embryo incubation and larval rearing success (Kock et al. 2006), and they may be consumed by omnivorous fishes (Anders et al. 2002).

Predation and Competition due to Changes in Fish Species Composition

The combined direct and indirect effects of habitat changes, as well as introduced species, have substantially altered biological community structure and species composition across all levels of the food chain (Anders 1991; Paragamian 1994; Anders and Richards 1996; Snyder and Minshall 1996; Anders et al. 2000; Paragamian 2002; Anders et al. 2002). This has impacted system productivity, food availability, competition, and predation (Anders et al. 2002). Populations of many native resident fishes have collapsed, including kokanee and burbot.

7.6.3 Plans, Objectives & Strategies

Primary co-managers for white sturgeon in this reach: *Kootenai Tribe of Idaho, Idaho Department of Fish and Game, British Columbia Ministry of Lands, Forests, and Natural Resource Operations, Canadian Columbia River Inter-Tribal Fish Commission, Canada Dept. of Fisheries and Oceans, U.S. Fish and Wildlife Service, and the Montana Department of Fish, Wildlife, and Parks*

Kootenai River White Sturgeon Recovery Implementation Plan and Schedule; 2005-2010

In conjunction with regional co-managers, the Kootenai Tribe of Idaho developed the Kootenai River White Sturgeon Recovery Implementation Plan and Schedule in 2005, with support from the Bonneville Power Administration (KTOI 2005). This document delineated research, monitoring, and evaluation actions believed necessary to protect, rehabilitate, and maintain Kootenai River white sturgeon in conjunction with activities highlighted in the population's recovery plan (USFWS 1999). Information in this document is intended to complement current recovery plan activities and provide information valuable to its update.

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

U. S. Fish and Wildlife Service Recovery Plan

The U. S. Fish and Wildlife Service recovery plan, adopted in 1999, identifies a long-term goal of downlisting and delisting Kootenai white sturgeon when the population becomes self-sustaining. Short-term objectives included reestablishing natural recruitment and preventing extinction by an implemented conservation aquaculture program. The plan suggested that downlisting would be appropriate when short-term criteria are achieved.

Three criteria for reclassification or downlisting were identified:

1. Natural production occuring in at least 3 different years of a 10-year period. A naturally-produced year class was defined as when at least 20 juveniles were sampled at more than 1 year of age.
2. Stable or increasing population. This includes juveniles released from the conservation aquaculture programeach year for a 10-year period in numbers large enough to produce 24 to 120 sturgeon surviving to sexual maturity.
3. A long-term flow strategy adequate to produce natural recruits.

The plan noted that recovery will not be complete until there is survival to sexual maturity, which may take upwards of 25 years for females and late teens for males. However, specific long-term goals or delisting criteria were not identified due to substantial uncertainties in population status, life history, biological productivity, and effects of flow augmentation.

The need to revise and update the 1999 recovery plan has been widely recognized (Paragamian et al. 2005). Plans for a revision are under discussion by the Kootenai River White Sturgeon Recovery Team, but have not been implemented. In the interim, a series of working goals and criteria[2] have been identified from a review of essential elements common to other sturgeon and salmon recovery plans (Dryer et al. 1993; UCWSRI 2002; LCFRB 2004; NMFS 2007; CDFO 2009; NMFS 2009).

However, the long-term recovery goal for the Kootenai River white sturgeon population is unchanged, which is to restore the population to a level where sturgeon are no longer threatened with extinction. Downlisting and subsequent delisting may occur when a species is naturally self-sustaining, where normal variation in abundance does not reduce numbers to a

[2] Criteria identified in the 1999 Recovery Plan have not been formally revised to address current status and information. Working criteria are being used to guide hatchery planning and implementation but have not been formally adopted into the Recovery Plan.

level from which recovery is unlikely or uncertain. Many recovery plans also include "broad sense" goals that recognize critical functions of a species within the ecosystem as well as social benefits related to opportunities for beneficial uses such as fishing.

The current working recovery goal for Kootenai white sturgeon is to ensure the persistence and viability of a naturally reproducing population as an essential element of an adequately functional ecosystem and a resource supporting traditional beneficial uses. In many Pacific salmon recovery plans, viability/delisting levels are specifically defined as having a <5% risk of extinction within a 100 years (approximately 20 generations). Corresponding standards have not been established for sturgeon, for which criteria must consider the unique life history and address a much longer time frame consistent with sturgeon longevity and the delayed onset of first maturity/reproduction, which are measured on a decadal scale.

Current recovery criteria related to long-term viability/delisting of Kootenai sturgeon are based on four population attributes: abundance, productivity, distribution/spatial structure, and diversity. The technical basis relating viability to these four attributes is adapted from salmon conservation, as reflected in the Viable Salmonid Population concept (McElhany et al. 2000). Specific attribute criteria applicable to Kootenai River white sturgeon are as follows:

<u>Abundance</u>

- A minimum adult population size of 2,500 (for downlisting) and a target adult population size of 8,000-10,000 (for delisting).

<u>Productivity</u>

- Naturally-produced recruitment and juvenile population sizes sufficient to support the desired adult population size.
- Stable or increasing trends in adult and juvenile numbers.
- Representative and stable size and age structure.

<u>Distribution/Spatial Structure</u>

- Distribution and use of habitats throughout the majority of the historical range.
- Breadth of distribution such that population is not vulnerable to any single human-caused catastrophic event (chemical spill for instance).

<u>Genetic Diversity</u>

- Stable genetic diversity (including frequencies of common and rare alleles).
- Effective population sizes adequate to allow for normal genetic and evolutionary processes.

In addition, a broad sense goal is to achieve adequate abundance/productivity to support significant subsistence harvests and recreational fishery uses. The recovery plan for Kootenai sturgeon identified three primary strategies: 1) flow augmentation to enhance natural reproduction; 2) identification of suitable habitat conditions for survival past the egg/larval stages, and 3) a conservation aquaculture program (USFWS 1999, Duke et al. 1999). Intensive efforts to date have failed to restore wild recruitment.

7.6.4 Programs, Projects, Actions & Schedules

The ultimate success of recovery efforts for the endangered Kootenai white sturgeon through natural production involves restoration of habitats and an ecosystem capable of sustaining a naturally spawning population with adequate biological diversity and productivity in supporting trophic levels to sustain an apex predator population (Anders 1991; Paragamian et al. 2001b; Anders and Richards 1996; Duke et al 1999; USFWS 1999; Anders et al. 2002; Paragamian et al. 2002). Meanwhile, an aquaculture program developed during the past 19 years will continue to be an effective tool for initially conserving a considerable portion of the genetics of the remnant wild population, increasing demographic vigor, and producing a more resilient age class structure, all of which serve to buffer the population otherwise facing eminent extinction.

Habitat Restoration

An ambitious habitat restoration project has been recently initiated by the KTOI, with the goal of large-scale ecosystem restoration. Phase 1A, bank stabilization to reduce sediment, has been completed. The first part of Phase 2, involving north channel restoration, was implemented during 2012. Other Phase 2 actions include riparian restoration, flow deflectors to create some scour pools, and increased channel complexity. Additional habitat actions may include placing rocky substrates at current spawning areas and increasing channel depth in straight and lower braided reaches. Phase 3, focused on restoring ecosystem functions, is anticipated to include larger scale floodplain reconnections, side channel restoration and reconnection, and riparian restoration, but will depend on identified opportunities given current agricultural uses in that area.

Hatchery Program

A conservation aquaculture program began in 1990 as a stopgap measure to preserve the remaining Kootenai sturgeon population (Ireland et al. 2002a, 2002b). The hatchery program spawns wild broodstock and rears juveniles for release at 1 or 2 years of age. The hatchery currently provides the only source of recruitment annually. It now appears likely that the next generation of sturgeon will be produced primarily or entirely by the conservation hatchery program. Barring some unforeseen habitat or natural production development, the hatchery will continue to provide the only immediate means of conserving the native genetic material, rebuilding a healthy age class structure, and preventing extinction in the short-term.

The Kootenai sturgeon hatchery program is a critical element in a cooperative, international conservation and recovery effort for endangered Kootenai River white sturgeon. This effort is being coordinated and implemented through a federally convened recovery team. The recovery team includes representatives from the U. S. Fish and Wildlife Service, Kootenai Tribe of Idaho, Idaho Department of Fish and Game, Montana Department of Fish, Wildlife and Parks, University of Idaho, Army Corps of Engineers, Bonneville Power Administration, Cramer Fish Sciences, British Columbia Ministry of Lands, Forests, and Natural Resource Operations, Canada Department of Fisheries and Oceans, and British Columbia Hydropower.

Near- and long-term objectives are identified for the aquaculture program in order to address conservation-related risks over time (Box 2). Near-term objectives focus primarily on the current generation that includes the declining remnant wild population. Near-term objectives help plot a course forward from a population's current demographic and genetic condition to future desired conditions. Long-term objectives involve future generations, including fish produced primarily in the hatchery from the remnant wild generation, and any natural recruits in the interval until the last wild fish dies or becomes scenescent. Long-term objectives provide a vision of the ultimate destination. Near-term objectives establish a sound foundation for meeting the long-term objectives.

Box 2. Period-specific objectives of the conservation aquaculture program to protect and restore Kootenai white sturgeon (periods describe the interval during which related risks are manifested).

Near-Term Objectives

1. Prevent demographic extinction by replacing failed natural recruitment.
2. Establish an increasing trend and broad distribution of ages and sizes in the wild population in order to ensure future sustainability.
3. Preserve and express native genetic, phenotypic, and life history diversity by capturing and spawning significant numbers of representative broodstock.
4. Provide contingencies for uncertain future availability of wild broodstock and prospects for restoring natural recruitment.
5. Inform recovery strategies by using hatchery fish to identify limiting life stages and habitat capacity.

Long-Term Objectives

6. Avoid annual spawning stock limitation where too few fish might be available to capitalize on favorable natural spawning conditions in any year (or to continue to provide hatchery broodstock).
7. Minimize, to the extent possible, the time interval between the functional extinction of remaining wild adults and maturation of the first hatchery generation.
8. Maintain an effective population size in the wild adequate to avoid genetic bottlenecks that risk loss of diversity or inbreeding depression in the next generation.
9. Avoid significant detrimental impacts of hatchery fish on natural production due to competition, predation, or disease magnification.
10. Avoid hatchery selection or domestication that might reduce future fitness or viability.

Hatchery releases of 200,274 juveniles from 1992 through 2011 have established a wild population of hatchery-reared fish of approximately 16,000 sturgeon surviving at least one year in the wild (Beamesderfer and Garrison 2013). The program continues to be refined based on new information. Current plans call for the construction of a new sturgeon hatchery facility (Twin Rivers) to complement historical programs at the Kootenai River Tribal Fish Hatchery in Bonners Ferry and the Freshwater Fisheries Society of Canada facility at Ft. Steele. Corresponding changes in production targets are identified in Table 13.

Table 13. Annual production in current and planned facilities relative to program objectives.

	Current facilities [a]	Proposed Facility Capacity		
		Total	Kootenai	Twin Rivers
Broodstock number	24	Up to 45	Up to 18	Up to 27
Families produced [b]	12-18	Up to 30	Up to 12	Up to 18
Fish/family	1,000-1,500	500-1,000	500-1,000	500-1,000
Total releases per year	10,000-15,000	15,000-30,000	6,000-12,000	9,000-18,000

[a] *Includes Kootenai Tribal Hatchery in Bonners Ferry and fail-safe Kootenay Sturgeon Hatchery in B. C. All broodstock holding and spawning occurs at the Kootenai Tribal Hatchery. A portion of the fertilized eggs are transported to the Kootenay Sturgeon Hatchery for rearing in the fail-safe program.*

[b] *Family is defined as offspring of one pair of parents.*

7.6.5 Needs & Uncertainties

The following challenges and uncertainties need to be addressed for the Kootenay Lake/Kootenai River white sturgeon management unit:

- Ability to maintain genetic diversity. Will program be able to capture enough of the wild population diversity needed to avoid a deleterious genetic founder effect in the next generation? Can hatchery practices successfully preserve the remaining array of life history, genetic, phenotypic and behavioral characteristics of the wild population?
- Adequacy of potential broodstock. Will adequate numbers of broodstock be available to sustain the hatchery program as the wild population continues to decline?
- Ability to rebuild natural age structure needed for recovery. Will release numbers and survival rates be adequate to rebuild the natural age structure and provide the next generation of broodstock?
- Ability to restore natural habitats. Can habitat and ecosystem restoration efforts restore conditions suitable for natural production?
- Ability to sustain commitment to program. Will the implementing partners be able to maintain a high level of commitment to the success and support of the program?

7.7 LOWER SNAKE (ICE HARBOR DAM TO LOWER GRANITE DAM)

The Lower Snake management unit extends on the Snake River from Ice Harbor Dam, near the Snake/Columbia River confluence (RM 9.7) to Lower Granite Dam (RM 107.5). The reach also contains two other mainstem dams: Lower Monumental Dam (RM 41.6) and Little Goose Dam (RM 70.3). The dams are all run-of-the-river dams, meaning that they pass water at the same rate it enters.

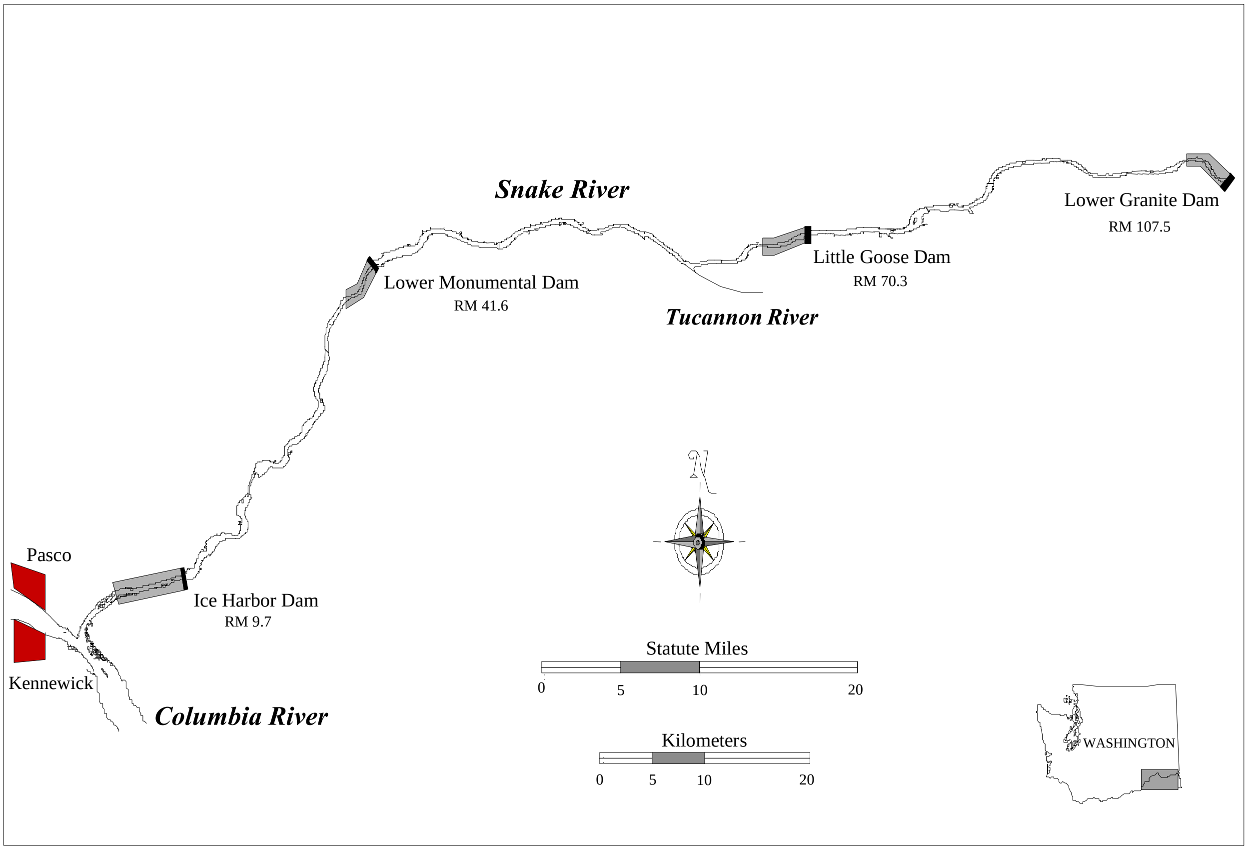


Figure 40. Lower Snake (Ice Harbor Dam to Lower Granite Dam) Management Unit.

7.7.1 Status

Stock assessments show that white sturgeon density, growth, and fitness in Ice Harbor, Lower Monumental, and Little Goose reservoirs is less than for lower Columbia Basin sturgeon populations (Ward et al. 1999; Beamesderfer et al. 1995; DeVore et al. 1995). The relative lack of juvenile fish and a lopsided age structure with proportionally more older individuals indicates recruitment problems in the three reservoirs (Ward et al. 1999).

White sturgeon spawn in the tailraces immediately below the dams. Researchers have documented white sturgeon spawning in Ice Harbor Reservoir within 3.9 km downstream from Lower Monumental Dam, in Lower Monumental Reservoir within 1.0 km of Little Goose Dam, and in Little Goose Reservoir between 1.3 and 5.8 km downstream from Lower Granite Dam.

The researchers believe spawning occurs in other nearby locations in the reservoirs, but that it is unlikely that spawning occurs much further downstream because of a decline in water velocity (Parsley and Kappenman 2000).

WDFW conducted its last stock assessment for white sturgeon in Ice Harbor Reservoir in 1996 and in Lower Monumental and Little Goose reservoirs in 1997. The populations in Lower Monumental and Little Goose reservoirs were reassessed in 2012, results of which are expected in 2013. An assessment of the population in Ice Harbor Reservoir scheduled for 20132 has been postponed until 2014. During the 1996 and 1997 assessments, a total of 1,538 individual white sturgeon were captured. Catch rates were greatest in the lowermost sections of each reservoir at the start of the survey period, with fish redistributing themselves upstream as river flow decreased in late summer (Ward 1998).

WDFW used a modified Schnabel estimator to come up with an estimate of 1,460 white sturgeon in the 110-209 cm FL size class in Ice Harbor Reservoir, with a 95% confidence interval of 1,090-2,190 fish. Expanding catches of all size classes ≥54 cm FL by adjusting for gear size selectivity resulted in a total population estimate of 4,830 fish. Given a calculated surface area of 3,198 hectares (ha) for Ice Harbor Reservoir, they determined the density of white sturgeon ≥54 cm FL was 1.51 sturgeon/ha (Ward 1998).

The focus of 1997 work was in Lower Monumental and Little Goose Reservoirs. WDFW estimated the abundance of 110-209 cm FL white sturgeon in Lower Monumental Reservoir to be 2,230 and that of the Little Goose white sturgeon population to be 4,180 (Ward et al. 1999). The lack of younger fish in Ice Harbor and in Lower Monumental reservoirs led investigators to characterize the population as recruitment-limited. This conclusion has since been supported by results of Age-0 index sampling conducted from 1997-1998 through 2004 in Ice Harbor and Little Goose reservoirs.

7.7.2 Limiting Factors & Threats

Habitat Fragmentation

Dams in this reach restrict white sturgeon migration and create several subpopulations that have limited access to spawning and rearing habitats. Habitat in the reach does not fully support all life stages, resulting in sporadic successful natural recruitment and small population sizes.

Habitat Diversity, Quality and Quantity

Dam construction and operation has transformed the historic natural river habitat in this reach of the Snake River into three reservoirs. The reservoirs covered historical floodplains and inundated past riparian vegetation that contributed to the food web. Sediments carried downstream from the upper watershed have settled on the reservoir floors, covering much of the bottom substrates.

Flows and Flow Variation

Flow regulation has limited seasonal and annual fluctuations that provide behavior cues and suitable spawning or rearing conditions.

Predation

Changes in the reach favor a much different aquatic community of prey, predators, and competitors. This has increased predation on white sturgeon.

7.7.3 Plans, Objectives & Strategies

> ***Primary co-managers for white sturgeon in this reach:*** *Washington Department of Fish and Wildlife, Columbia River Inter-Tribal Fish Commission*

No single comprehensive management document for white sturgeon currently exists for this management unit. White sturgeon are designates an aquatic "species of interest" in the Northwest Power and Conservation Council's Lower Snake River Mainstem Subbasin Plan. The species is of cultural and ecological significance to stakeholders in the region, but not enough information was available to support its selection as focal species (NPCC 2004).

7.7.4 Programs, Projects, Actions & Schedules

White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers Upstream from Bonneville Dam

WDFW, ODFW and CRITFC periodically conduct white sturgeon assessments in the three lower Snake River reservoirs. Initial population assessments were completed in 1996 and 1997. The populations in Lower Monumental and Little Goose reservoirs were assessed again in 2012. The population in Ice Harbor Reservoir is scheduled to be assessed in the summer of 2014. These assessments provide information on white sturgeon life histories, distribution and current population sizes, and the foundation for the development of appropriate management goals and objectives.

Areas immediately downstream of the four lower Snake River dams were surveyed in 1998 in an attempt to quantify white sturgeon spawning and rearing habitat (Anglin and Skalicky 2000). This work was never completed and the availability of spawning habitat has not been characterized.

Age-0 production was indexed from 1997-1998 through 2004 in Ice Harbor and Little Goose reservoirs. This activity was eliminated in response to project funding reductions in 2005.

7.7.5 Needs & Uncertainties

The following challenges and uncertainties need to be addressed for the Lower Snake River white sturgeon management unit:

- Information on population trends is lacking and periodical estimates of adult and sub-adult white sturgeon abundance needs to be conducted more frequently.
- Population dynamics and carrying capacity needs to be characterized for each reservoir.
- Information is needed to determine and quantify critical habitat use by early life stages, and effects of environmental variables (including flow, flow variability, and contaminants) on year class strength.

- Information is needed to identify predators and quantify early life-stage predation losses.
- Uncertainty concerning how hydro operations (flow routing and load) influence spawning success (below the spillway, powerhouses, and transition zones); egg deposition; dispersal of free swimming embryos; and access to rearing habitats.
- Uncertainty in productivity– Annual growth, length-weight relationship, and relative weight of white sturgeon inhabiting the lower Snake River.
- Information needed on the loss of the historic prey base, and nutritional value of current pry base on population productivity.
- Uncertainty regarding reservoir-specific genetic diversity, population differentiation, and gene flow.
- Uncertainty remains regarding potential benefits and risks associated with implementing a conservation aquaculture program in this management unit to help meet productivity objectives.

7.8 Middle Snake (Lower Granite Dam to Hells Canyon Dam)

The Lower Granite Dam to Hells Canyon Dam reach includes 53 km of slack water in Lower Granite Reservoir and 172 km of free-flowing Snake River. From Lower Granite Reservoir at Lewiston to the Hells Canyon tailrace, the river forms the Washington-Idaho border for the first 59 km and the Oregon-Idaho border for 114.2 km. Several large tributaries join this reach of the Snake River, including the Clearwater, Salmon, Grande Ronde, and Imnaha Rivers.

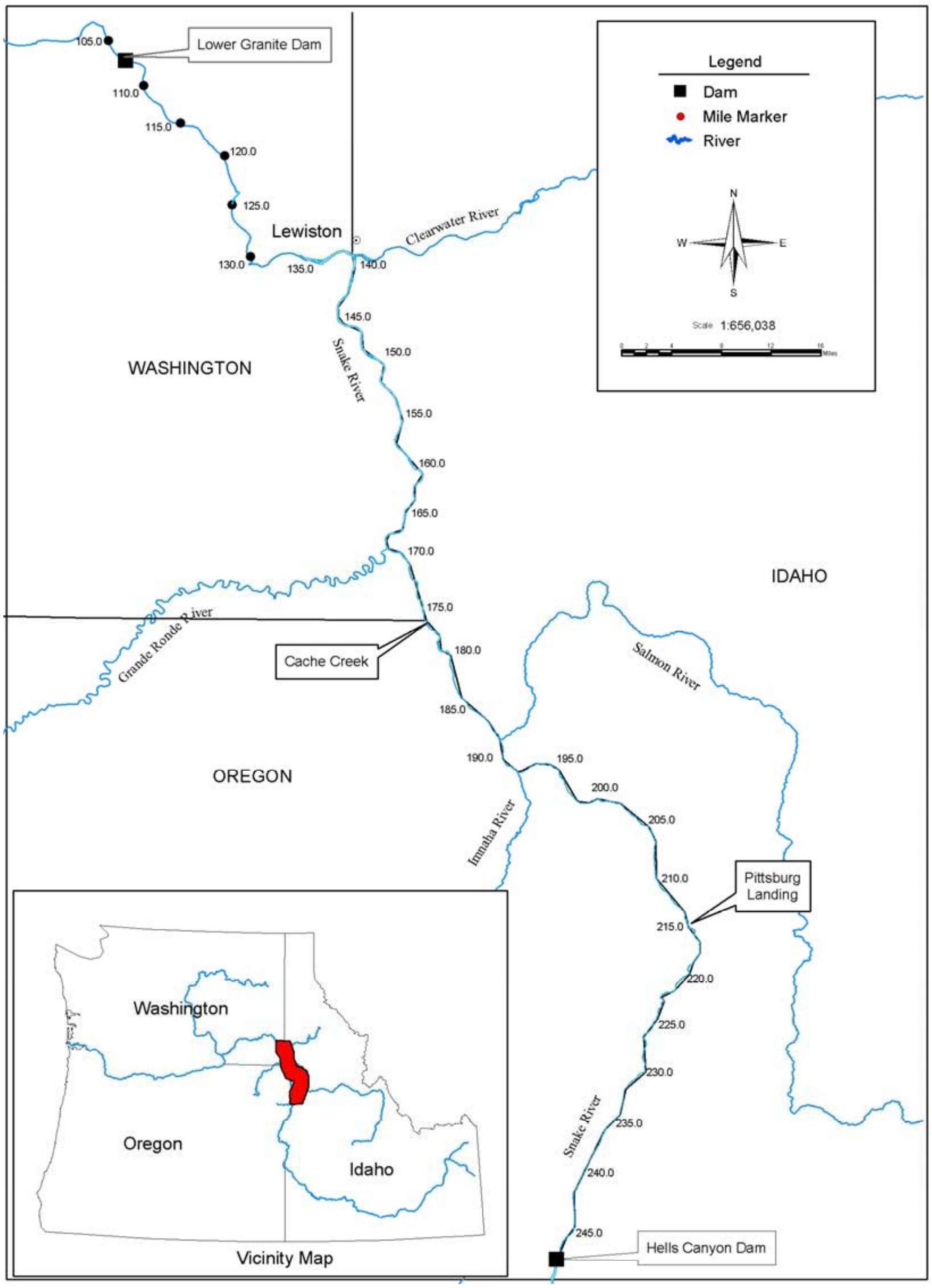


Figure 41. Middle Snake (Lower Granite Dam to Hells Canyon Dam) Management Unit.

7.8.1 Status

The white sturgeon population inhabiting the Lower Granite-Hells Canyon reach is one of two productive, self-sustaining populations in the Snake River. IDFG manages white sturgeon in this reach as a core conservation population.

Three studies to describe the white sturgeon population in the reach were conducted in 1972 (Coon et al. 1977), 1984 and 1985 (Lukens 1985), and 1997 to 2000 (Everett and Tuell 2001, Lepla et al. 2001). During the most recent survey (1997–2000), Idaho Power Company captured 923 white sturgeon (including 270 recaptures) between Granite Rapids (RM 238) and the mouth of the Salmon River (RM 188) with 27,658 setline and 681 angling hours of effort (Table 6) (Lepla et al. 2001). As part of cooperative sampling efforts during the 1997–2000 period, the Nez Perce Tribe captured 876 sturgeon (with 106 recaptures) from the Salmon River confluence downstream to Lower Granite Dam (Everett and Tuell 20016). The abundance of white sturgeon in the Hells Canyon—Lower Granite reach was estimated at 3,625 individuals greater than 70 cm TL or 17 fish/km, based on combined data from concurrent Idaho Power Company (Hells Canyon Dam to the Salmon River) and Nez Perce Tribe (Salmon River to Lower Granite Dam) efforts. Previous surveys of sturgeon abundance provided higher estimates in the segment (8,200–12,250, Coon et al. 1977; 3,955, Lukens 1985); however, these previous surveys used dissimilar gear and sampling protocols and therefore cannot be directly compared (Cochnauer 2002).

The studies showed a the positive response in the size structure below Hells Canyon Dam following changes in sturgeon fishing regulations in 1972. Fishing regulations regarding sturgeon harvest became increasingly restrictive until 1972, when catch-and-release regulations were enacted in Idaho for the sturgeon populations in the Snake and Salmon Rivers. Based on recent survey data, the sturgeon population below Hells Canyon Dam has responded well from impacts of prior catch-and-keep sport regulations (Cochnauer et al. 1985; Cochnauer 2002). While juvenile fishless than 92 cm TL continue to dominate the population, abundance of fish greater than 92 cm TL has steadily grown since the 1970s. The percentage of sturgeon 92 to 183 cm TL, the legal harvestable size prior to 1972, has increased from 4 percent in 1972–1975 (Coon et al. 1977), to 18 percent in 1982–1984 (Lukens 1985), to 29 percent in 1997–2000 (Lepla et al. 2001). Similarly, sturgeon greater than 183 cm TL have also responded positively to the restrictions as evidenced by increasing abundance from 2 percent in 1982–1984 to 18 percent in 1997–2000.

The size structure of the Hells Canyon population suggests continuous recruitment. Stock assessments conducted between 1972 and 2000 have indicated positive and consistent recruitment trends with juveniles dominating the population. The population currently supports both catch-and-release sport (including incidental angling mortality) and tribal harvest fisheries. While the current density estimate (17 fish/km) is lower than the target density (32 fish/km) identified in IDFG's white sturgeon management plan, the Lower Granite-Hells Canyon sturgeon population remains genetically diverse. It also exhibits a healthy population structure, based on the current stock structure dominated by juveniles, wide range of size classes, and stages of maturity from immature juveniles to reproductive adults. Nevertheless, Chandler et al. (2002) reported that project operations at Hells Canyon Dam could reduce the availability of modeled habitat for early life stages of white sturgeon during low-flow years.

7.8.2 Limiting Factors and Threats

Habitat Fragmentation

The Lower Granite to Hells Canyon reach is the most natural reach, except for the Salmon River, among all of the impounded Snake and Columbia River reaches inhabited by sturgeon (Cochnauer 2002). While white sturgeon in the reach remain fragmented from other Columbia and Snake River sturgeon populations, they maintain access to diverse habitats that in most years can meet life history requirements for all life stages.

Habitat Diversity, Quality and Quantity

The upper 108 km is a series of short rapids, long riffles and dispersed pools (>9 m depth) resulting in a gradient of 1.8 m/km, while the lower section, with a gradient of 0.7 m/km, consists of a few, relatively deep pools and long deep runs, interspersed with minor riffle areas. The reservoir extends approximately 5 km upstream beyond the confluence of the Snake and Clearwater rivers (at the community of Lewiston, Idaho). Near the upper end of the reservoir, the river emerges from Hells Canyon, the deepest canyon in North America.

Sediments and contaminants may collect in depositional zones in the impounded reach above Lower Granite Reservoir, reducing the suitability of rearing habitats for sturgeon early-life stages (Nez Perce Tribe 2005). The prevalence of fine sediments in these reaches eliminates the interstitial spaces that serve as temporary refugia for yolk-sac larvae before exogenous feeding commences (Brannon et al. 1995). Early-life stages of white sturgeon are extremely sensitive to environmental pollutants as a result of their benthic orientation (Detlaff et al. 1993).

Flows and Flow Variation

Upstream impoundments influence the annual hydrograph pattern of the free-flowing section of the Snake River below Hells Canyon Dam (IDFG 2008). Hells Canyon Dam operates as a peaking facility from late spring until the fall, so flows and surface elevation of the free-flowing section of river near the dam may vary. Water levels are held relatively constant during the fall through spring to protect spawning, incubation, and early rearing environments for listed fall Chinook salmon (*Oncorhynchus tshawytscha*). The upstream impoundments alter the natural hydrograph by increasing fall, winter, and early spring flows, while reducing peak flows and extending the duration of high flows later in the spring (IDFG 2008; Coon et al. 1977).

Water Quality

<u>Dissolved Oxygen and Dissolved Gases</u>

Water quality below Hells Canyon Dam does not meet Idaho or Oregon state standards for dissolved oxygen and total dissolved gases during brief periods of most years. For instance, dissolved oxygen levels measured in the tailrace of Hells Canyon Dam can drop to as low as 2.8 mg/l for several weeks during late summer. Spilling water in excess of approximately 2,500 cfs at Hells Canyon Dam can also increase total dissolved gases to supersaturation levels that exceed the 110 percent protective standard (Myers and Parkinson 2002).

Temperature

River regulation has changed the physical characteristics of rearing habitats for white sturgeon by increasing water temperatures in the slow-moving impounded reaches and by trapping sediments behind dams. The effects of elevated, summer temperatures in the reservoir reaches upriver of Lower Granite Reservoir on white sturgeon physiology have yet to be studied, but seasonally high water temperatures during low flow years may impact growth and survival rates of early-life stages. (Nez Perce Tribe 2005).

7.8.3 Plans, Objectives & Strategies

> ***Primary co-managers for white sturgeon in this reach:*** *Idaho Department of Fish and Game, Idaho Power Company, Nez Perce Tribe, Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife*

Three separate plans influence the management of white sturgeon in this reach of the Snake River: IDFG's Management Plan for the Conservation of Snake River White Sturgeon in Idaho (2010), Idaho Power Company's Snake River White Sturgeon Conservation Plan (2005), and the White Sturgeon Management Plan in the Snake River between Lower Granite and Hells Canyon Dams (Nez Perce Tribe 2005). Though similarities exist among the three plans, the scope, objectives and strategies differ substantially.

Management Plan for the Conservation of Snake River White Sturgeon in Idaho

IDFG manages white sturgeon in the Hells Canyon–Lower Granite reach as a Core Conservation Population. The plan is available at: http://fishandgame.idaho.gov/cms/fish/programs/whiteSturgeon.pdf. The plan outlines the following management objectives:

1. Manage as a self-sustaining population supported by natural recruitment with no influence from hatchery-reared fish.
    a. The IDFG will not stock, nor will we permit other entities to stock hatchery-reared white sturgeon into this reach.
    b. In collaboration with other states and the Nez Perce Tribe, juvenile and adult white sturgeon of wild origin may be translocated into this reach from upstream reaches where spawning and larval rearing habitat is lacking. Such translocations will be limited in scope, and be accompanied by monitoring activities to assess survival, movement, growth, and spawning behavior.
2. In cooperation with Idaho Power Company, the population will be evaluated at approximately 10-year intervals.
    a. Standardized sampling methods will be used to describe trends in abundance, size structure, fish condition, and recruitment.
3. More intensively sample the lower and middle reaches of the Salmon River to describe abundance, size structure, and origin of white sturgeon and interaction with Snake River fish.

   a. Use standardized sampling methods to establish baseline for trend monitoring.
4. Maintain or increase catch-and-release fishing opportunity for white sturgeon.
   a. Evaluate angler effort, catch, and satisfaction.
   b. Assess effects of catch-and-release angling on white sturgeon populations, and evaluate regulation changes if needed.
   c. Promote sturgeon angling and proper fish handling techniques to minimize angling-related mortalities.
   d. Targeted enforcement patrols will occur in this reach.

Snake River White Sturgeon Conservation Plan (IPC 2005)

The Snake River White Sturgeon Conservation Plan (IPC 2005) is intended to serve as a master plan for guiding the implementation of feasible mitigation measures for Snake River white sturgeon populations impacted by Idaho Power Company's hydroelectric projects. These measures are designed to help ensure the species' long-term persistence and restore opportunities for beneficial use.

The plan's long-term goal is to mitigate for Idaho Power Company project-related impacts in order to provide for healthy populations of white sturgeon in each reach of the Snake River between the mouth of the Salmon River and Shoshone Falls, not including the reach between Upper Salmon Falls and Lower Salmon Falls dams. The plan defines a healthy population as a reproducing population capable of sustaining itself at or near carrying capacity of available habitat without artificial propagation, resilient in the face of natural variations in habitat conditions, and capable of supporting a tribal and non-tribal harvestable fishery. Achieving healthy sturgeon populations in each reach of the Snake River within the anticipated term (approximately 30 years) of new hydroelectric project licenses is unlikely or impossible, given current population numbers and the extent of habitat degradation and alteration to the Snake River ecosystem. Therefore, this goal is considered long term and likely beyond the anticipated term of the new project licenses.

Short-term objectives will be necessary to guide mitigation actions within the time frame of new hydroelectric project licenses. In addition, a guiding principle in the development of this conservation plan is that actions to restore sturgeon populations in depressed reaches must not place existing viable sturgeon populations (Bliss–C.J. Strike and Hells Canyon–Lower Granite populations) at risk. Sturgeon populations below Bliss and Hells Canyon dams currently provide self-sustaining natural recruitment and are considered genetically diverse (M. Powell; University of Idaho; personal communication to the WSTAC, August 8, 2002). Because of these conditions, mitigation actions undertaken in the various reaches of the Snake River should not threaten the persistence and viability of these two remaining wild sturgeon populations.

The short-term objectives of the conservation plan include maintaining and/or enhancing population viability and persistence of Snake River white sturgeon below Hells Canyon Dam. s; and 2) where feasible, begin to reestablish recruitment to sturgeon populations where natural recruitment is severely limited.

White Sturgeon Management Plan in the Snake River between Lower Granite and Hells Canyon Dams

The overall goal of the Nez Perce white sturgeon management plan (2005) is to maintain a viable, persistent population of white sturgeon between Lower Granite and Hells Canyon Dams that can support an annual sustainable harvest. The plan is available at http://www.cbfwa.org/rfms/index.cfm. The following objectives may be used to measure the progressive response of the population to implemented management actions:

- A natural, stable age structure comprising both juveniles and a broad spectrum of spawning age-classes;
- Stable or increasing numbers of both juveniles and adults;
- Consistent levels of average recruitment to ensure future contribution to reproductive potential;
- Stable genetic diversity comparable to current levels;
- A minimum level of abundance of 2,500 adults to minimize extinction risk; and
- Provide an annual sustainable harvest of 5 kg/ha.

To achieve management objectives, the Nez Perce Tribe worked with a Biological Risk Assessment Team to developed potential mitigative actions. Identified strategies and actions include enhancing growth and survival rates by restoring anadromous fish runs and increasing passage opportunities for white sturgeon, reducing mortality rates of early life stages by modifying flows in the Hells Canyon Reservoir, reducing mortality imposed by the catch and release fishery, augmenting natural production through translocation or hatchery releases, and assessing detrimental effects of contaminants on reproductive potential. These proposed actions were evaluated by assessing their relative potential to affect population growth rate and by determining the feasibility of their execution, including a realistic timeframe (short term, midterm, long term) for their implementation and evaluation.

7.8.4 Programs, Projects, Actions & Schedules

Programs and actions to benefit white sturgeon between Lower Granite and Hells Canyon Dams are summarized below. Section 7.9.4 of the Upper Snake management unit describes IDFG and Idaho Power Company program direction in more detail.

Habitat Protection and Enhancement

Future hydropower operations at Snake River dams in Idaho have largely been determined by the FERC in new licenses issued in the recent past, so the ability to affect significant operational changes to benefit sturgeon are remote. In the Hells Canyon reach of the Snake River, where stronghold wild populations exist, the IDFG will promote protection of habitat conditions. The IDFG will work with state and federal regulatory and management agencies and the Nez Perce Tribe to optimize white sturgeon spawning success, incubation, and juvenile rearing conditions. This is especially critical with core conservation populations that are supported entirely by natural recruitment. IDFG staff will continue to provide technical support and input to state and federal regulatory agencies regarding land management, water quality, hydropower operations, and flow management.

Population Monitoring

Intensive assessments of white sturgeon abundance and size structure will occur in the reach at approximately 5–10 year intervals. Idaho Power Company, as a condition of federal licenses for their hydropower facilities, will conduct these scheduled surveys in consultation and/or cooperation with IDFG. Additional sampling by IDFG and Idaho Power Company will occur as needed. Additionally, the Nez Perce Tribe will continue assessing the white sturgeon population in the Hells Canyon reach and Salmon River. The IDFG and the Nez Perce Tribe have a data sharing agreement in place. Standard methods to collect white sturgeon will include setlines, hook and line, gillnetting, and trawling. White sturgeon egg deposition and reproductive success may be monitored in some reaches using egg mats, bottom trawls, or other methods as they are developed. Methods to sample larvae and juveniles will be refined to better document conditions that influence reproduction. Abundance estimates will be based on multiple mark-recapture efforts in each reach, and size structure in each reach will be described using the total catch from standard sampling gear. Radio telemetry may be used to evaluate habitat use, spawning movements, to monitor translocated fish, or to assist in angling-related mortality assessments.

Evaluating Fishing-related Mortality

The IDFG examines white sturgeon angling effort and catch in relation to population status and trends for key river reaches, including below Hells Canyon Dam. Angling effort and catch data are collected by traditional creel survey or by some form of mandatory reporting for sturgeon anglers.

Translocation

Translocation is the capture and transport of wild white sturgeon from one reach to another. Translocation objectives may vary on a reach-by-reach basis. Theoretically, adult fish could be moved from reaches that lack spawning and larval rearing habitat into reaches where natural spawning can be successful (e.g., from the C.J. Strike reach to the Bliss reach). Surplus juvenile fish might be collected from productive reaches and used to supplement populations where little or no recruitment exists. Such translocations would artificially restore some degree of connectivity and potentially genetic exchange among reaches.

Any translocation efforts will include a comprehensive evaluation plan to document survival, movement, growth, diseases, and reproductive activities. The IDFG will consult with state fish and wildlife agencies (Oregon, Washington) and the Nez Perce Tribe if donor fish are identified from river reaches along shared state boundaries.

Conservation Aquaculture

IDFG considers conservation of wild, self-sustaining populations of white sturgeon a top priority. Core Conservation Populations will be strictly managed for natural recruitment. The IDFG will not stock, nor will it permit other entities to stock hatchery-reared white sturgeon into Core Conservation Populations. In reaches where natural recruitment is absent or inadequate, hatchery supplementation is one management option to maintain population abundance and diversity and provide fishing opportunity. The long-term genetic risks of hatchery supplementation will need to be carefully weighed against the shorter-term risks of population collapse. Any future supplementation will only involve Snake River F1 generation fish. As with other management alternatives, supplementation will be evaluated on a reach-by-reach basis, and any supplementation program will include broodstock (genetic) objectives and an evaluation component to monitor survival, movement, and growth of stocked fish.

A conservation aquaculture program was proposed by Idaho Power Company as part of their White Sturgeon Conservation Plan (Idaho Power Company 2005). The Nez Perce is also considering hatchery supplementation as part of a multi-pronged approach whereby to implement its management plan. Priority management actions identified by the Nez Perce include: producing juvenile white sturgeon in a hatchery and releasing them into the management area; collecting juvenile white sturgeon from other populations in the Snake or Columbia rivers and releasing them into the management area; and restoring white sturgeon passage upriver and downriver at Lower Snake and Idaho Power dams. An integral part of this approach is the continual monitoring of performance measures to assess the progressive response of the population to implemented actions, to evaluate the actions' efficacy toward achieving objectives, and to refine and redirect strategies if warranted (Nez Perce Tribe 2005).

The IDFG will take a cautious approach to conservation aquaculture for white sturgeon, but will consider such a program where appropriate. A cooperative agreement would have to be developed and signed by the parties prior to development of an aquaculture program for Snake River white sturgeon. The IDFG will consider white sturgeon supplementation only after the following conditions have been met:

- Careful consideration of the impacts on naturally producing populations both locally and in downstream reaches of the Snake and Columbia rivers;
- Available habitat, food sources, hydrological conditions, and water quality have been improved or restored, and
- To the extent possible, hydropower operation constraints and other limiting environmental factors have been addressed.

Before making any decision on an aquaculture program for Snake River white sturgeon, the IDFG will coordinate with the appropriate stakeholders, most notably adjacent state fish and wildlife managers and the Nez Perce Tribe.

In addition, the Nez Perce Tribe, as per treaty rights associated with the Nez Perce Tribe Treaty of 1855, conducts research on white sturgeon populations in the Hells Canyon-Lower Granite Dam reach of the Snake River and has a tribal harvest fishery in the same area. The IDFG cooperates with the Nez Perce Tribe in this reach of the Snake River.

7.8.5 Needs & Uncertainties

The following challenges and uncertainties need to be addressed for the Middle Snake River white sturgeon management unit:

- Information is limited regarding adult white sturgeon abundance, stock structure, temporal trends, and genetic diversity.
- Need to characterize population dynamics and carrying capacity in the reach.

- Uncertainty regarding life stage(s) at which survival limitations (bottlenecks) occur.
- Uncertainties associated with a conservation aquaculture program. Of particular concern is downstream drift of stocked fish into core conservation populations and the long-term risks to genetic integrity. Based on past practices of using very few adult broodstock, closely related progeny, and large numbers stocked with documented downstream movement, there is reason for anxiety. That is why the IDFG is proposing conservation aquaculture as a potential tool to be used only after very careful deliberation involving key stakeholders.

7.9 UPPER SNAKE (HELLS CANYON DAM TO SHOSHONE FALLS)

This management unit extends from Hells Canyon Dam to Shoshone Falls. The natural passage barrier of Shoshone Falls (RM 614.7) represents the uppermost natural distribution of white sturgeon in the Snake River. White sturgeon in this river reach became increasingly isolated with the construction of dams culminating with the completion of Lower Granite Dam in the early 1970's.

Descriptions for seven reaches in the Snake River between Hells Canyon Dam and Shoshone Falls are provided separately below:

- *Hells Canyon Dam to Brownlee Dam*. Hells Canyon Dam (RM 247.6) forms the lower bound of the 22-mile segment to Oxbow Dam and impounds water the entire length of the reach. Hells Canyon Reservoir has a maximum depth of 60 m and is characterized by steep rocky shorelines with basalt outcrops and talus hill slopes (Lepla and Chandler 2001). During July and August of low-flow years, up to 52 percent of the reservoir's bottom 2 m exhibits poor water quality conditions, such as low DO levels (Lepla and Chandler 2001). Major tributaries within this segment include Pine Creek and Indian Creek, which together contribute an average annual flow of 400 cfs.

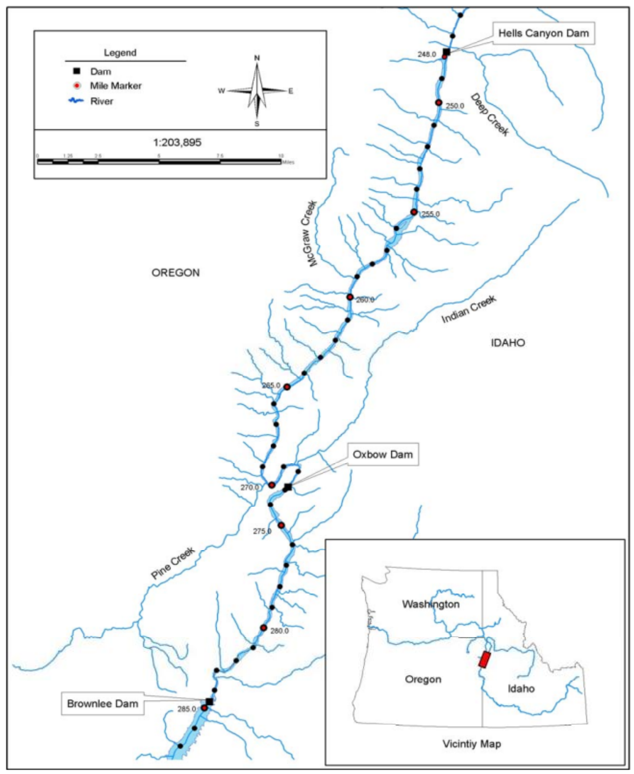


Figure 42. Hells Canyon Dam to Brownlee Dam.

  The Oxbow Reservoir pool extends 19 km upstream to Brownlee Dam, with suitable white sturgeon spawning habitat probably limited to only the area immediately below Brownlee Dam. Technically, there is no free-flowing river section, but flowing water does occur for in the reach for a limited distance during spill events, or when the dam turbines are in operation. Oxbow Reservoir experiences poor water quality conditions during low flow years as the result of receiving anoxic water from Brownlee Reservoir (Myers et al. 2001; Lepla et al. 2001). Low dissolved oxygen levels lethal to white sturgeon can comprise up to 73 percent of the bottom 2-m in Oxbow Reservoir during low flow years. The potential for natural recruitment in this reach is low due to inadequate spawning habitat, poor water quality, and egg/larval transport out of the system. Downstream drift from upriver populations also appears unlikely. The IDFG does not believe that a self-sustaining white sturgeon population or fishery is possible under current conditions. With only 1 km of free-flowing water, the -,number of white sturgeon that can be supported and maintained in this section is also in question. In addition, draft tubes (turbine outlets) in Brownlee Dam have not been retrofitted to exclude white sturgeon prior to turbine startups. If sturgeon were more abundant, frequent turbine strikes and mortalities would be expected.

- *Brownlee Dam to Swan Falls Dam.* This reach is the longest segment of free-flowing river remaining in the Snake River. The river stretch from Brownlee Dam to Swan Falls Dam is characterized by a canyon section in the upper 22 km and a broader river valley in the lower 167 km. Brownlee Reservoir inundates approximately 88 km of riverine habitat. Swan Falls Dam is operated as a load attenuating facility. Water quality in this reach has been severely degraded by nutrient loading from irrigation returns, and industrial and municipal sources (Harrison et al. 1999; Myers et al. 2001). The hydrograph is influenced by water storage and irrigation demands in the upper Snake River Basin. As with the other facilities, the hydrograph is bimodal and the high flows that trigger spawning may not coincide with suitable spawning temperatures. The reach displays little evidence of sturgeon natural recruitment and has low population abundance.

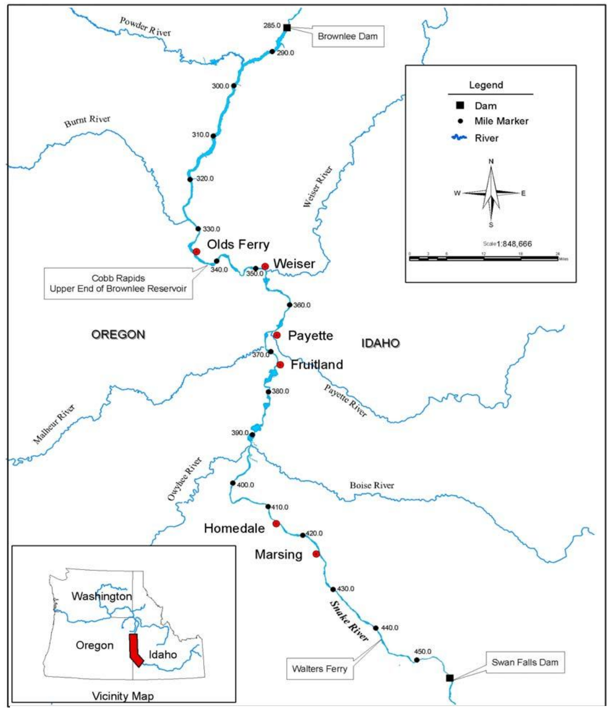


Figure 43. Brownlee Dam to Swan Falls Dam.

- *Swan Falls Dam to C.J. Strike Dam.* This reach has 40 km of free flowing water comprised mainly of low gradient shallow run habitat, island complexes, and a few deep pools. There are no rapids or narrow channels to create high velocity zones and turbulent upwelling often associated with staging and spawning areas (Lepla and Chandler 2001). Only during median or high water years is spawning habitat available and then only immediately below C.J. Strike Dam. There is no spawning habitat available at 141–283 cubic meters per second through the C.J.

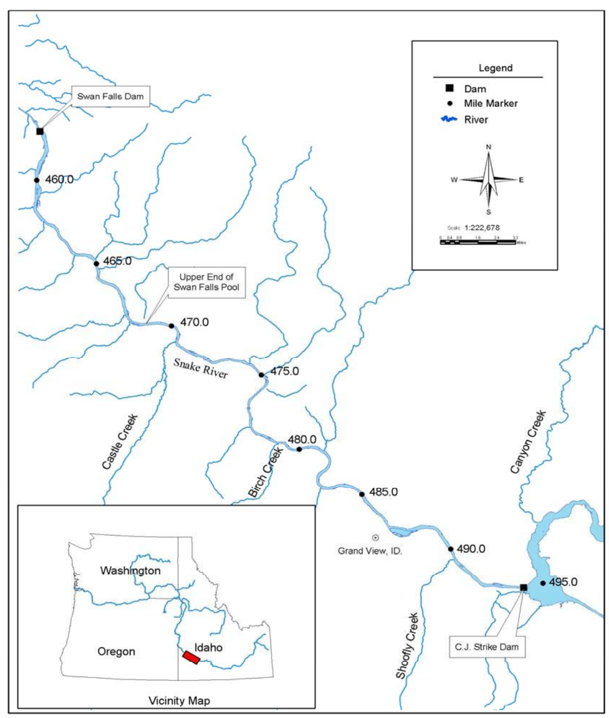


Figure 44. Swan Falls Dam to C.J. Strikes Dam.

Strike Dam project (Lepla and Chandler 1997). Historically, it is unlikely white sturgeon used this low gradient section for spawning, but they may have reared in this section. Cochnauer (1983) suggested that the small population of white sturgeon between C.J. Strike and Swan Falls dams was spawning-limited as fish less than 5 years of age were not captured. In addition, the population may have been declining since the early 1970s (Cochnauer et al. 1985).

- *C.J. Strike Dam to Bliss Dam*. There are 106.7 km of free-flowing Snake River and reservoir between C.J. Strike Dam and Bliss Dam. C.J. Strike Reservoir is 38 km long. The reach includes over 16 km of flowing river in the canyon area from Bliss Dam to Clover Creek, located near the community of King Hill. The river falls about 1 m/km through this canyon reach. It is typically fast, deep (10 m) run-type habitat characterized by intermittent pools and riffles, with several pools up to 15 m deep. For about 53 km below Clover Creek, the river flows through relatively flat terrain with lower gradient (0.6 m/km) down to the C.J. Strike Pool. The run-type habitats in this reach support abundant aquatic vegetation in the summer. There are a few pools 8–10 m deep and one pool over 20 m deep. Historically, many of the larger white sturgeon (272–363 kg) harvested in Idaho came from this section, and this reach still supports the most abundant and productive population upstream from Hells Canyon Dam (Cochnauer 1983).

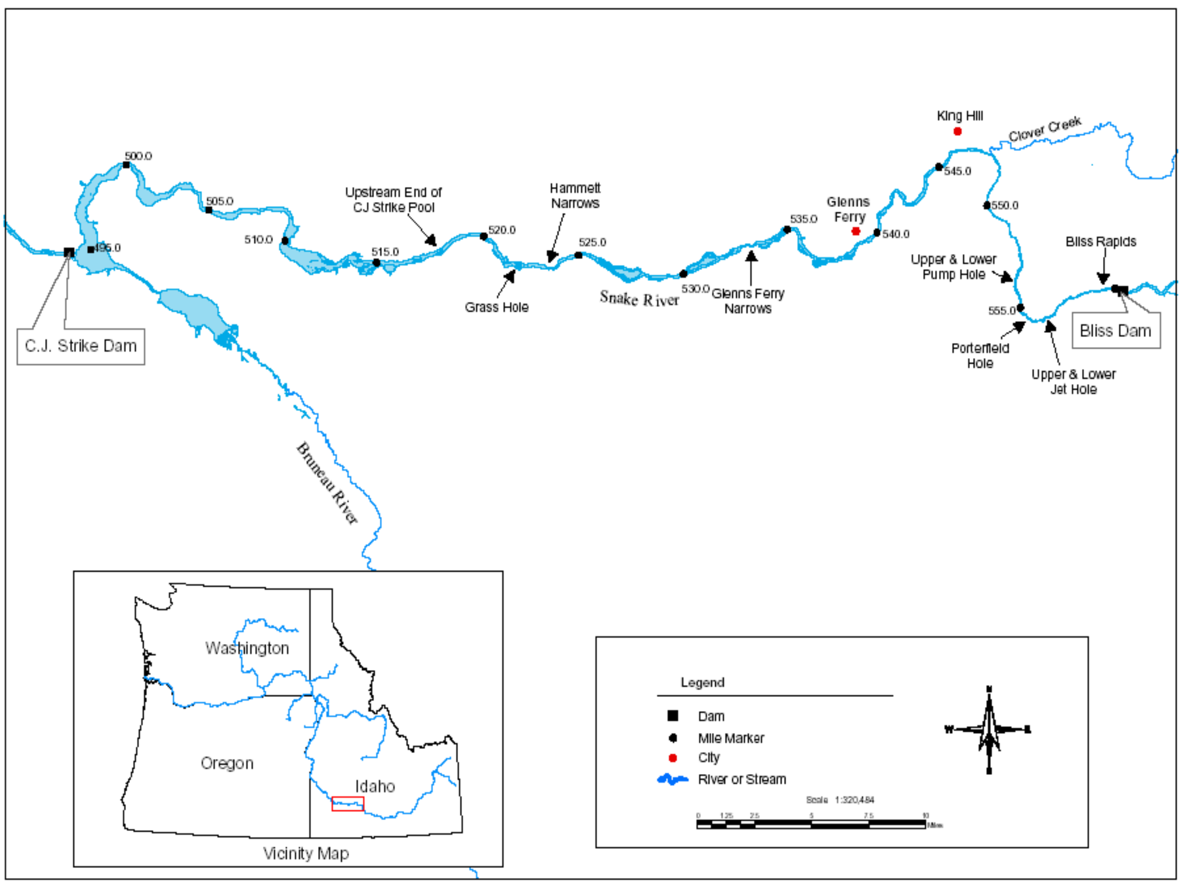


Figure 45. C.J. Strikes Dam to Bliss Dam.

- *Bliss Dam to Lower Salmon Falls Dam*. This reach exhibits a narrow river canyon with bedrock and rubble lining a number of deep pools and rapids. The Malad River, formed below the confluence of the Big and Little Wood rivers, enters in the reach. For 13 km below Lower Salmon Falls Dam, the river is free-flowing with relatively high gradient (2m/km) and provides white sturgeon spawning habitat even at the lowest flows (Cochnauer 1983). Bliss Dam, constructed in 1950 at the site of a natural falls, impounds the lower 8 km of the reach.

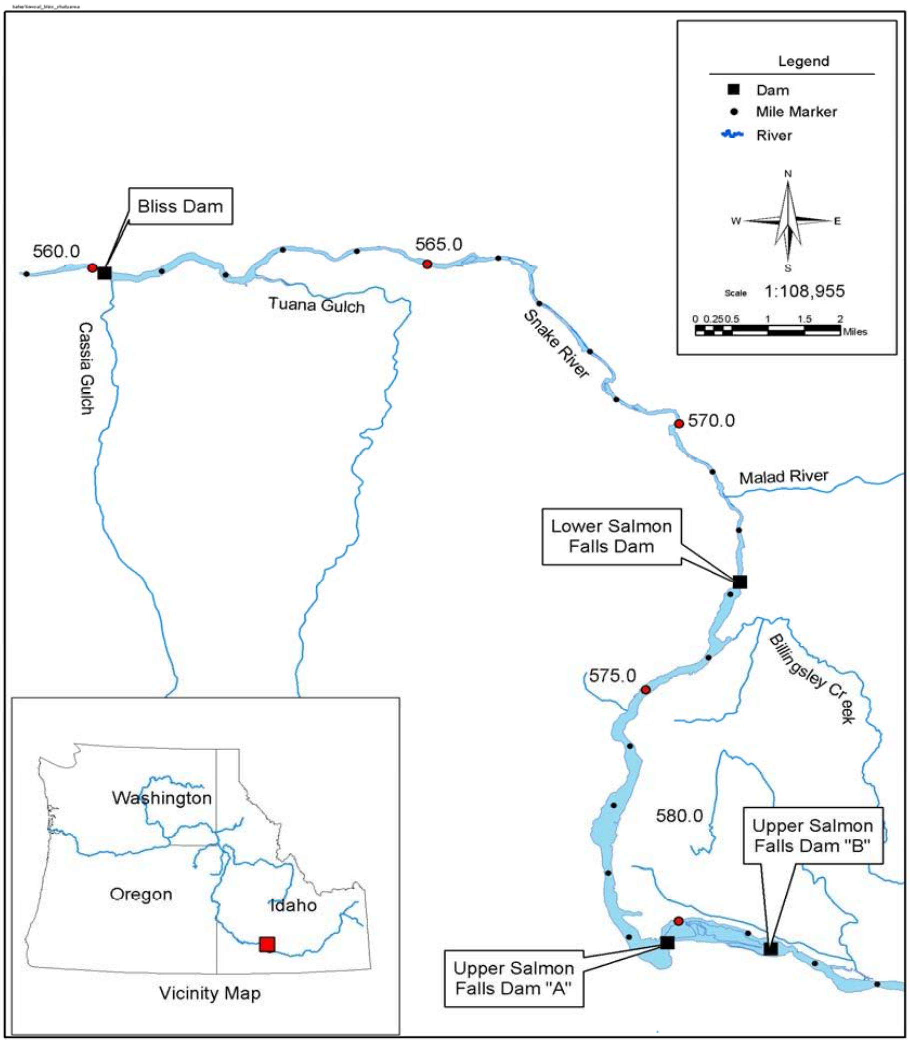


Figure 46. Bliss Dam to Upper Salmon Falls Dam.

- *The Lower Salmon Falls Dam to Upper Salmon Falls Dam*. This reach is part of a three-dam complex comprised mostly of reservoir habitat with the exception of a 1 km by-pass of Dolman Island. Flows in the braided bypass channels often are less than 14 cubic meters per second. A survey by IDFG in 1979–81 found no white sturgeon. Lukens (1981) concluded no spawning habitat was available for white sturgeon. The relatively close spacing between dams (11 km) limits the amount of available free flowing habitat and the short distance between dams is conducive to downstream losses of early life history stages through egg or larval drift. Establishment of a self-sustaining white sturgeon population in this section is very unlikely under these conditions.

- *Upper Salmon Falls Dam to Shoshone Falls.* The river segment between Upper Salmon Falls Dam and Shoshone Falls represents the uppermost natural distribution of white sturgeon in the Snake River. Upstream reservoir development and irrigation withdrawals and return flows have substantially altered both water quality and quantity compared to historical conditions. Flows passing over Shoshone Falls and through this reach are largely dependent on the water quantity passing Milner Dam (40 rkm upstream). In most years with average or below average runoff, the high spring flows are captured and stored upstream. In higher water years, the hydrograph is bimodal. Stream flow increases in late spring, decreases as irrigation withdrawal occurs, and then increases again in high water years as snow melt in the upper Snake River causes flows to exceed storage capacity and irrigation delivery. During the irrigation season, all of the water in the river can be diverted for irrigation purposes. There are several large rapids in this reach that can provide adequate spawning velocities, but high spring flows to disperse eggs and larvae beyond the spawning areas are absent in most years. The altered hydrograph can also remove or shift the peak spring flows out of synchronicity with suitable spawning temperatures.

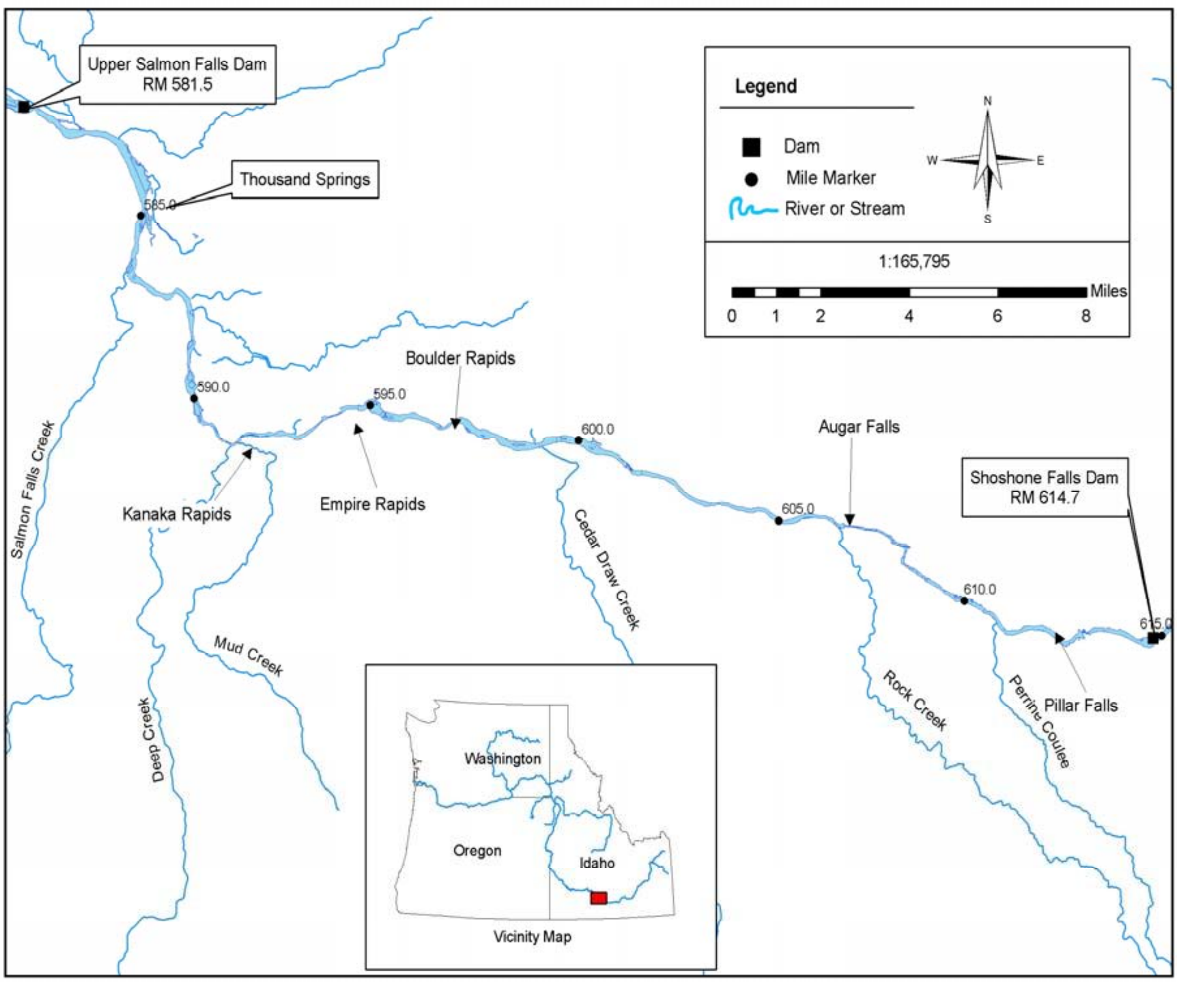


Figure 47. Upper Salmon Falls Dam to Shoshone Falls.

7.9.1 Status

The reach between C.J Strike and Bliss Dams supports the most abundant and productive white sturgeon population upstream from Hells Canyon Dam (Cochnauer 1983). The white sturgeon population in this reach is considered viable and is managed as a core conservation population. Snake River reaches between Hells Canyon and Swan Falls dams, and upstream between Bliss Dam and Shoshone Falls contain only small populations and show little or no detectable recruitment. These populations consist of small numbers of adults and are not self-sustaining. IDFG recognizes the populations in these reaches as conservation populations. Abundance estimates range from 21 white sturgeon > 70 cm TL in the reach between Lower Salmon Falls and Upper Salmon Falls dams, to over 3,000 fish in the reach between C.J. Strike and Bliss dams (IDFG 2008).

Table 14. White sturgeon abundance estimates for subpopulations above Hells Canyon Dam (IDFG 2008).

Subpopulation	Abundance	Comments
Hells Canyon	3,625	> 24 inches (2002)
Oxbow		None captured (1998)
Brownlee	166	> 28 inches (2001)
Swan Falls	566	> 35 inches (2007)
C.J. Strike	4,025	> 28 inches (2010)
Bliss	83	> 28 inches (2004)
Lower Salmon Falls	21	> 28 inches (2009)
Upper Salmon Falls	346	> 28 inches (2008)

7.9.2 Limiting Factors & Threats

Habitat Fragmentation

Historically, the free-flowing Snake River in Idaho provided a diversity of habitats for white sturgeon and readily supported all life stages. Prior to the early 1900s, white sturgeon had access to all available habitats for various life history functions (e.g., spawning), and for seasonal foraging opportunities. However, beginning as early as 1900, construction of dams and reservoirs on the Snake River in Idaho significantly altered habitats available for white sturgeon, fragmenting the river corridor into smaller segments and reducing access to critical habitats such as spawning areas.

Because white sturgeon are confined to relatively short river reaches that lack the required habitats for all life stages, such as in current conditions, many of the fragmented reaches of the Snake River show little or no evidence of natural sturgeon recruitment. Small populations within abbreviated river segments are especially vulnerable to stochastic or catastrophic events. In short river segments, populations are vulnerable to downstream losses (past dams) that reduce production potential (IPC 2005). Eggs and larvae are most likely lost from short river segments, essentially preventing recruitment in the reach where they were spawned.

Older age classes of white sturgeon have also been documented to move downstream of dams on the Snake River. This is particularly true of shorter reaches. This downstream movement either occurs through dam turbines (entrainment) or through spill gates during periods of spill (IPC 2005). Idaho Power Company field sampling conducted to date has identified at least 59, mostly hatchery sturgeon, which have successfully moved downstream past one or more Snake River dams between American Falls and Swan Falls. There is a significant risk of mortality for larger white sturgeon because they are more likely to be struck by turbine blades than are smaller fish.

Generally, the relationship between stream reach length and natural recruitment and stock structure is evident in the Snake River with one exception. The Swan Falls-Brownlee reach is the longest segment of free-flowing river remaining in the Snake River, but displays little evidence of natural recruitment and has low population abundance. This is likely caused by poor water quality (IPC 2005). The other remaining long reaches of the Snake River support the four largest populations of white sturgeon (in descending order) and include: Hells Canyon-Lower Granite, Bliss-C.J. Strike, Shoshone Falls-Upper Salmon Falls, and C.J. Strike-Swan Falls. The remaining five reaches of the Snake River show little to no evidence of natural recruitment.

Flow and Flow Variation

The natural seasonal flow regime of the Snake River has been altered by dams and water management, which has resulted in shifts in the timing and volume of peak runoff conditions. Today, the Snake River is extensively regulated to provide water for agriculture, hydropower, and municipalities, and to provide flood control. Several dams in the upper Snake River basin were constructed to store and divert water for irrigation purposes. This has resulted in alterations in the natural hydrograph and significant reductions in the natural flow of the Snake River (IDFG 2008).

Intensive water management practices in the upper Snake River basin for irrigation and flood control can substantially alter the magnitude and timing of the spring hydrograph downstream. Reductions in spring flows are primarily the result of refilling of U.S. Bureau of Reclamation upstream storage projects drafted during the previous year to meet irrigation storage contracts. These water management practices also shift peak spring flows so that they do not occur in tandem with optimum spawning temperatures for white sturgeon (IPC 2005). This can result in reduced spawning and early rearing habitats for white sturgeon. Recruitment of juvenile white sturgeon has been documented to be positively related to the volume of spring flow (Kohlhorst et al. 1989; Parsley and Beckman 1994; Miller and Beckman 1995; Brink and Chandler 2000; Chandler and Lepla 1997).

Hydropower operations can result in daily flow fluctuations downstream of projects for power generation and this can affect recruitment potential for white sturgeon (IPC 2005). Instream flow studies conducted by Idaho Power Company below Lower Salmon Falls, Bliss, C.J. Strike, and Hells Canyon dams have illustrated that load following or power peaking operations can substantially reduce the amount of spawning, incubation, and larval habitats for white sturgeon, particularly during low water years (IPC 2005). For instance, the estimated age structure of white sturgeon sampled in 2000 below Bliss Dam indicated that natural recruitment of white sturgeon was poor during below normal water years when aggressive load following operations occurred (1988, 1989, and 1990; Brink and Chandler 2000). In years with similar hydrology but limited or no load following (1992, 1993, and 1994), higher recruitment of white sturgeon occurred.

Water Quality

Water quality throughout the Snake River has been impacted by the cumulative effects of dam and reservoir construction, intensive agriculture, and industrial activities (Clark et al. 1998; Harrison et al. 2000). Much of the mainstem Snake River is listed as impaired or water quality-limited (IDEQ 2004, 1998). Observations from Clark et al. (1998) included declines in dissolved oxygen, increases in water temperature, elevated nutrient levels and other contaminants, and elevated total dissolved gases.

Water quality degradation generally worsens during low flow periods from mid to late summer. During the summer irrigation season when water demand is high, reduced stream flows and irrigation return water combine to cause degraded water quality conditions. Return flows to the Snake River are significant contributors of nitrogen, phosphorus, pesticides, and sediment (Clark et al. 1998).

White sturgeon can be directly impacted by degraded water quality conditions in the Snake River. Generally, it occurs in the summer when multiple stressors combine such as low flows, elevated water temperature, and low dissolved oxygen levels. Mortalities of white sturgeon directly attributable to degraded water quality conditions have been documented in the Snake River in the Swan Falls Dam to Brownlee Dam reach (Grunder et al. 1993).

7.9.3 Plans, Objectives & Strategies

> ***Primary co-managers for white sturgeon in this reach:*** *Idaho Department of Fish and Game and Idaho Power Company*

Two existing management plans are applicable to this area. These include the Management Plan for the Conservation of Snake River White Sturgeon in Idaho (IDFG 2008) and the Snake River White Sturgeon Conservation Plan (IPC 2003).

Additionally, the Snake River White Sturgeon Technical Advisory Committee (WSTAC), a group of federal, state, and tribal representatives established in 1991 to provide technical guidance to Idaho Power Company during its relicensing efforts, outlined recommended measures specific to each reach (IPC 2005).

Management Plan for the Conservation of Snake River White Sturgeon in Idaho (IDFG 2008)

The IDFG plan contains the following objectives and measures for white sturgeon in Snake River reaches above Hells Canyon Dam:

<u>Hells Canyon Dam to Brownlee Dam</u>

IDFG Management Objectives

1. If a decision is made to pursue conservation aquaculture, it will be done in concert with the appropriate stakeholders and only after careful deliberation. All stocked fish will be externally marked and PIT tagged prior to release to differentiate them from wild fish.

2. Based on evaluation, develop recommendations for long-term management strategies. Poor survival, low angler success, or high emigration rates would immediately trigger termination of the stocking program.

WSTC Recommended Measures

- Improve water quality conditions in Oxbow and Hells Canyon reservoirs to meet Idaho and Oregon state criteria for dissolved oxygen, temperature and total dissolved gas.
- Transplant reproductive-sized adult white sturgeon to increase number of spawners and improve white sturgeon productivity.
- Monitor success of white sturgeon spawning and early life history survival.
- Develop experimental conservation aquaculture plan in cooperation with the IDFG, Nez Perce Tribe, and ODFW.
- Develop a genetics plan that addresses the current status and implications of translocations and potential hatchery introductions.
- Conduct periodic population assessments (time frame TBD).
- Take no action.
- Determine the feasibility of passage at the Hells Canyon Dam.
- Evaluate the feasibility of dam removal.
- Develop a schematic flow chart outlining PM&E measures with associated tasks, time frames, and decision points.

<u>Brownlee Dam to Swan Falls Dam</u>

IDFG Management Objectives

1. Pending results of Idaho Power Company's water quality assessment, we will strive to increase abundance of white sturgeon.

    a. The white sturgeon population in this reach is considered to be below carrying capacity. Based on available habitat in the upper 22 km, the IDFG believes this reach should support 600–700 white sturgeon (all age classes combined). This objective should be considered preliminary and subject to adjustment as monitoring data are available.

    b. Population objectives may be achieved by translocating wild juvenile fish from other Snake River reaches, supplementation with hatchery-reared fish, or a combination of these approaches.

    c. If a decision is made to pursue conservation aquaculture, it will be done in concert with the appropriate stakeholders and only after careful deliberation. All hatchery-reared white sturgeon will be externally marked and PIT tagged to differentiate them from wild fish.

    d. In cooperation with Idaho Power Company, the population will be intensively evaluated at approximately 10-year intervals. Standardized sampling methods will be used to describe trends in abundance, size structure, fish condition, and recruitment.

2. Maintain or increase fishing opportunity for white sturgeon
   a. Evaluate angler effort, catch, and satisfaction.
   b. Assess effects of catch-and-release angling on white sturgeon, and evaluate regulation changes if needed.
   c. Promote sturgeon angling and proper fish handling techniques.

WSTAC Recommended Measures

- Conduct an assessment of water quality-related impacts on early life stages of white sturgeon development.
- Improve water quality conditions in Brownlee Reservoir to meet Idaho and Oregon state criteria for dissolved oxygen, temperature, and total dissolved gas.
- Translocate reproductive-sized adult white sturgeon to increase number of spawners and improve white sturgeon productivity.
- Monitor success of white sturgeon spawning and early life history survival.
- Develop experimental conservation aquaculture plan.
- Conduct periodic population assessments (time frame TBD).
- Develop a genetics plan that addresses the current status and implications of translocations and potential hatchery introductions.
- Monitor for changes in genotype frequency.
- Increase flow.
- Restore/protect riparian areas to hasten water quality improvements.
- Develop a schematic flow chart outlining PM&E measures with associated tasks, time frames, and decision points.

<u>Swan Falls Dam to C.J. Strike Dam</u>

IDFG Management Objectives

1. Increase abundance of white sturgeon
   a. The white sturgeon population in this reach has declined somewhat from 1997 to 2007 with current abundance estimated at 566 fish. While there is no established method to estimate carrying capacity, the IDFG believes this reach should support 700–800 white sturgeon (all age classes combined). In cooperation with Idaho Power Company, the population will be intensively evaluated at approximately 5-year intervals with the next scheduled survey around 2011. Standardized sampling methods will be used to describe trends in abundance, size structure, fish condition, and recruitment.
   b. If natural recruitment or downstream drift of juvenile white sturgeon occurs and is considered adequate, no supplementation will occur, and the population will

be allowed to increase naturally. If no recruitment or inadequate recruitment is documented, hatchery supplementation and/or translocation of wild fish may be considered to maintain the population and fishing opportunity.

   c. If a decision is made to pursue conservation aquaculture, it will be done in concert with the appropriate stakeholders and only after careful deliberation. All hatchery-reared white sturgeon will be externally marked and PIT tagged to differentiate them from wild fish.

2. Maintain or increase fishing opportunity for white sturgeon
   a. Evaluate angler effort, catch, and satisfaction.
   b. Assess effects of catch-and-release angling on the white sturgeon population and evaluate regulation changes if needed.
   c. Promote sturgeon angling and proper fish handling techniques.

WSTAC Recommended Measures

- Provide habitat conditions suitable for white sturgeon spawning: a) Transplant reproductive- sized adults to suitable spawning habitat in the Bliss–C.J. Strike reach, b) Determine feasibility of a trapping facility to collect spawners (or all ages) below C.J. Strike Dam, and c) Determine feasibility of developing spawning and incubation habitats below C.J. Strike Dam.
- Determine feasibility of reduced trash bar spacing to minimize turbine entrainment and impingement of white sturgeon.
- Conduct periodic population assessments (time frame TBD).
- Develop a genetics plan that addresses the current status and implications of translocations.
- Monitor for changes in genotype frequency.
- Evaluate effect of catch-and-release angling below C.J. Strike Dam in cooperation with IDFG.
- Implement seasonal run-of-river project operations at C.J. Strike Dam during the spawning, incubation, and larval life stages of white sturgeon development (time frame TBD).
- Improve water quality in C.J. Strike Reservoir: a) Develop specific measures to improve water quality conditions through consultation with IDEQ within the framework of the C.J. Strike–Succor Creek TMDL implementation and the § 401 water quality certification process for the C.J. Strike Project, and b) Study discharge options at C.J. Strike Dam to improve water quality conditions.
- Determine feasibility of passage at C.J. Strike Dam.
- Develop a schematic flow chart outlining PM&E measures with associated tasks, time frames, and decision points.

C.J. Strike Dam to Bliss Dam

IDFG Management Objectives

1. Manage as a self-sustaining population supported by natural recruitment with no

influence from hatchery-reared fish.

   a. The IDFG will not stock, nor will we permit other entities to stock hatchery-reared white sturgeon into this reach.
   b. In collaboration with IPC, adult white sturgeon of wild origin may be translocated into this reach from adjacent reaches where spawning and larval rearing habitat is lacking. Such translocations will be limited in scope, and be accompanied by monitoring activities to assess survival, movement, and spawning behavior.
   c. In collaboration with IPC, wild juvenile white sturgeon may in some years be collected and translocated to other Snake River reaches where natural recruitment is poor and/or wild populations are depressed.

2. Maintain or increase catch-and-release fishing opportunity for white sturgeon.
   a. Evaluate angler effort, catch, and satisfaction.
   b. Assess effects of catch-and-release angling on white sturgeon populations, and evaluate regulation changes if needed.
   c. Promote sturgeon angling and proper fish handling techniques to minimize angling-related mortalities.
   d. Promote targeted enforcement patrols in this reach.
3. In cooperation with Idaho Power Company, the population will be intensively evaluated at approximately 5-year intervals. Standardized sampling methods will be used to describe trends in abundance, size structure, fish condition, and recruitment. IPC will conduct annual indexing efforts targeting young-of-year and age 1 white sturgeon to better understand population recruitment trends, length at age relationships, and underlying limiting factors.

WSTAC Recommended Measures

- Conduct periodic population assessments (time frame TBD).
- Develop a genetics plan that addresses the current status and implications of translocations.
- Monitor for changes in genotype frequency.
- Implement seasonal run-of-river project operations at Bliss Dam during the spawning, incubation, and larval life stages of white sturgeon development (time frame TBD).
- Improve water quality in C.J. Strike Reservoir: a) Develop specific measures to improve water quality conditions through consultation with IDEQ within the framework of the C.J. Strike–Succor Creek TMDL implementation and the § 401 water quality certification process for the C.J. Strike Project, and b) Study discharge options at C.J. Strike Dam to improve water quality conditions.
- Develop a schematic flow chart outlining PM&E measures with associated tasks, time frames, and decision points.

<u>Bliss Dam to Lower Salmon Falls</u>

IDFG Management Objectives

1. If a decision is made to pursue conservation aquaculture, it will be implemented in concert with the appropriate stakeholders and only after careful deliberation. All hatchery-reared white sturgeon will be externally marked and PIT tagged to differentiate them from wild fish. Consider translocations of adults or juveniles from other areas or consider the utility and risks associated with a conservation aquaculture program.
    a. Use spot creel surveys or other techniques (e.g., mail surveys) to assess angler participation, catch rates, and satisfaction.
    b. Conduct periodic (every 3–5 years) within and below this reach to assess survival, growth, condition, and movement of stocked fish.

WSTAC Recommended Measures

- Evaluate status of hatchery sturgeon stocked during 1989–1994.
- Evaluate the historical white sturgeon hatchery plants (genetic implications, competition with wild fish, movement, etc.).
- Conduct periodic population assessments (time frame TBD).
- Develop experimental conservation aquaculture plan.
- Develop a genetics plan that addresses the current status and implications of potential hatchery introductions.
- Implement seasonal run-of-river project operations at Lower Salmon Falls Dam during the spawning, incubation, and larval life stages of white sturgeon development (time frame TBD).
- Monitor water quality response from measures implemented in § 401 water quality certification for the Mid-Snake projects.
- Develop a schematic flow chart outlining PM&E measures with associated tasks, time frames, and decision points.

<u>Lower Salmon Falls Dam to Upper Salmon Falls Dam</u>

IDFG Management Objectives

1. If a decision is made to pursue conservation aquaculture, it will be done in concert with the appropriate stakeholders and only after careful deliberation. All hatchery-reared white sturgeon will be externally marked and PIT tagged to differentiate them from wild fish.
2. Based on evaluation, develop recommendations for long-term management strategies. Poor survival, low angler success, or high emigration rates would trigger termination of the stocking program.
3. Conduct periodic (every 3-5 years) within and below this reach to assess survival,

growth, condition, and movement of stocked fish.

4. Use spot creel surveys or other techniques (e.g., mail survey) to assess angler participation, catch rates, and satisfaction.

WSTAC Recommended Measures

- Conduct periodic population assessments (time frame TBD).
- Determine feasibility of passage in the North Channel below Upper Salmon Falls Dam.
- Develop a schematic flow chart outlining PM&E measures with associated tasks, time frames, and decision points.

<u>Upper Salmon Falls Dam to Shoshone Falls</u>

IDFG Management Objectives

1. Increase abundance of white sturgeon
    a. The white sturgeon population in this reach is considered to be below carrying capacity. In cooperation with Idaho Power Company, the population will be intensively evaluated at 5-year intervals. Standardized sampling methods will be used to describe trends in abundance, size structure, fish condition, and recruitment.

    b. If natural recruitment of juvenile white sturgeon occurs and is considered adequate, no additional supplementation is warranted, and the population will be allowed to increase naturally over time. If no recruitment or inadequate recruitment is documented, additional but limited supplementation may be considered to maintain the population and fishing opportunity. Supplementation could occur via translocation or conservation aquaculture.

    c. If a decision is made to pursue conservation aquaculture, it will be done in concert with the appropriate stakeholders and only after careful deliberation. All hatchery-reared white sturgeon will be externally marked and PIT tagged to differentiate them from wild fish.
2. Maintain or increase fishing opportunity for white sturgeon
    a. Evaluate angler effort, catch, and satisfaction.
    b. Assess effects of catch-and-release angling on the white sturgeon population and evaluate regulation changes if needed.
    c. Promote sturgeon angling and proper fish handling techniques.

WSTAC Recommended Measures

- Monitor success of white sturgeon spawning and early life history survival.
- Determine and obtain minimum flows needed for white sturgeon spawning, incubation, and early rearing life stages.
- Translocate reproductive-sized adults to increase number of spawners in the population

and improve white sturgeon productivity.

- Develop experimental conservation aquaculture plan.
- Conduct periodic population assessments (time frame to be determined [TBD]).
- Evaluate the historical white sturgeon hatchery plants (genetic implications, competition with wild fish, movement, etc.).
- Develop a genetics plan that addresses the current status and implications of translocations and potential hatchery introductions.
- Develop a schematic flow chart outlining PM&E measures with associated tasks, time frames, and decision points.

Snake River White Sturgeon Conservation Plan (IPC 2005)

The Snake River White Sturgeon Conservation Plan (IPC 2005) is intended to serve as a master plan for guiding the implementation of feasible mitigation measures for Snake River white sturgeon populations impacted by Idaho Power Company's hydroelectric projects. These measures are designed to help ensure the species' long-term persistence and restore opportunities for beneficial use.

The plan's long-term goal is to mitigate for Idaho Power Company project-related impacts in order to provide for healthy populations of white sturgeon in each reach of the Snake River between the mouth of the Salmon River and Shoshone Falls, not including the reach between Upper Salmon Falls and Lower Salmon Falls dams. The plan defines a healthy population as a reproducing population capable of sustaining itself at or near carrying capacity of available habitat without artificial propagation, resilient in the face of natural variations in habitat conditions, and capable of supporting a tribal and non-tribal harvestable fishery. Achieving healthy sturgeon populations in each reach of the Snake River within the anticipated term (approximately 30 years) of new hydroelectric project licenses is unlikely or impossible, given current population numbers and the extent of habitat degradation and alteration to the Snake River ecosystem. Therefore, this goal is considered long term and likely beyond the anticipated term of the new project licenses.

Short-term objectives are necessary to guide mitigation actions within the timeframe of new hydroelectric project licenses. The short-term objectives are to maintain and/or enhance population viability and persistence of white sturgeon below Bliss and Hells Canyon dams and, where feasible, begin to reestablish recruitment to populations where natural recruitment is severely limited. Population targets include population densities of 32 fish/km of usable habitat; naturally-produced recruitment to support the desired population structure (60% of the individuals between 60 and 90 cm TL, 30% between 90 and 180 cm TL, and 10% greater than 180 cm TL) of juveniles and adults; stable or increasing trends in juvenile and adult numbers; and genetic diversity similar to current levels.

Snake River White Sturgeon Technical Advisory Committee

The Snake River White Sturgeon Technical Advisory Committee has proposed the following management strategies: [3, 4]

- Conduct periodic population assessments (time frame TBD).
- Develop a genetics plan that addresses the current status and implications of translocations.
- Monitor for changes in genotype frequency.
- Determine the effect of translocation on donor population.
- Improve water quality conditions below Hells Canyon Dam to meet Idaho and Oregon state criteria for dissolved oxygen, temperature, and total dissolved gas.
- Implement seasonal run-of-river project operations at Hells Canyon Dam during the spawning, incubation, and larval life stages of white sturgeon development (time frame TBD). The intent of the WSTAC is not to enter into an aquaculture program without first fully exploring restoration of quality habitats and/or genetic implications of hatchery supplementation.
- Develop a schematic flow chart outlining PM&E measures with associated tasks, time frames, and decision points.

7.9.4 Programs, Projects, Actions & Schedules

Habitat Protection and Enhancement

Future hydropower operations at Snake River dams in Idaho have largely been determined by the FERC in new licenses issued in the recent past, so the ability to affect significant operational changes to benefit sturgeon are remote. Adequate flows and the timing of flows are critical to perpetuate spawning activities and promote egg incubation and growth of larval and juvenile white sturgeon. In the Bliss reach of the Snake River, where a stronghold wild population exists, the IDFG will promote protection of habitat conditions. This is especially critical with core conservation populations that are supported entirely by natural recruitment. IDFG staff will continue to provide technical support and input to state and federal regulatory agencies regarding land management, water quality, hydropower operations, and flow management.

Population Monitoring

Intensive assessments of white sturgeon abundance and size structure will occur in each reach at approximately 5–10 year intervals. Idaho Power Company, as a condition of federal licenses for their hydropower facilities, will conduct these scheduled surveys in consultation and/or

[3] Recommended measures do not indicate consensus, nor do they necessarily represent the views or the official positions of any individuals or agencies participating in the WSTAC.

[4] The intent of WSTAC is not to enter into a conservation aquaculture program without first fully exploring the restoration of quality habitat and/or genetic implications of hatchery supplementation.

cooperation with IDFG. Additional sampling by IDFG and Idaho Power Company will occur as needed. Standard methods to collect white sturgeon will include setlines, hook and line, gillnetting, and trawling. White sturgeon egg deposition and reproductive success may be monitored in some reaches using egg mats, bottom trawls, or other methods as they are developed. Methods to sample larvae and juveniles will be refined to better document conditions that influence reproduction. Abundance estimates will be based on multiple mark-recapture efforts in each reach, and size structure in each reach will be described using the total catch from standard sampling gear. Radio telemetry may be used to evaluate habitat use, spawning movements, to monitor translocated fish, or to assist in angling-related mortality assessments.

Evaluating Fishing-related Mortality

The effects of catch-and-release angling on white sturgeon populations are largely unknown. Even low levels of fishing-related mortality could impact population size structure and abundance, especially in reaches with poor habitat and low reproductive success, or where fish are concentrated below dams. White sturgeon angling effort appears to be increasing throughout the Snake River, but there has been no structured fishery monitoring so total effort and catch is largely unknown except for the intensively fished reach immediately below C.J. Strike Dam.

To assess losses associated with non-consumptive fisheries in Idaho, we propose to collaborate with other agencies, Idaho Power Company, and the Nez Perce Tribe. A greater challenge is to be able to effectively characterize the indirect and cumulative impacts of a strictly catch and release fishery on long- term survival, growth, productivity, and population viability (ODFW staff, personal communication).

The IDFG proposes to examine white sturgeon angling effort and catch in relation to population status and trends for key river reaches. The C.J. Strike reach was surveyed during 2007–2008 due to intensive angling pressure in a relatively short river section, but other reaches such as Bliss and Hells Canyon will be assessed as well. Angling effort and catch data will be collected by traditional creel survey or by some form of mandatory reporting for sturgeon anglers.

Fishing Regulations, Angler Education, and Enforcement

The IDFG will continue to provide barbless hook, catch-and-release fishing opportunity for Snake River white sturgeon. To minimize angling-related stress and mortality, anglers are prohibited from removing white sturgeon from the water once caught. Given the current status and productivity of wild populations, no harvest opportunity is expected for the foreseeable future. Other than the above fishing regulations, there are no other gear restrictions required when fishing for Snake River white sturgeon. In the state fishing rules, the IDFG suggests the use of specific terminal tackle but we do not currently require the use of such tackle (e.g., circle hooks, monofilament vs. braided line). Additional fishing restrictions are an option to be considered by the IDFG depending on population surveys, continuing research on mortality sources, and policy direction from the Idaho Fish and Game Commission.

The IDFG will continue to develop and distribute information on white sturgeon status and fishing opportunity in Idaho and will promote angling and fish handling techniques that minimize fishing-related mortality. Sturgeon angling tips, recommended terminal tackle, and proper handling methods are provided in the fishing rules proclamation book. The IDFG will also produce a video on white sturgeon biology, status, and fishing techniques for use at sports shows, fairs, and other public venues.

IDFG conservation officers will continue to educate the public and ensure compliance with regulations on white sturgeon fisheries. Highest priority for these efforts will be on reaches designated as Core Conservation Populations. Other reaches (Conservation Populations and Sportfish Populations) will receive focused enforcement effort as needed.

Translocation

Construction of Snake River dams has created nine artificial reaches with little or no genetic exchange among populations. Translocation is the capture and transport of wild white sturgeon from one reach to another. Translocation objectives may vary on a reach-by-reach basis. Theoretically, adult fish could be moved from reaches that lack spawning and larval rearing habitat into reaches where natural spawning can be successful (e.g., from the C.J. Strike reach to the Bliss reach). Surplus juvenile fish might be collected from productive reaches and used to supplement populations where little or no recruitment exists. Such translocations would artificially restore some degree of connectivity and potentially genetic exchange among reaches.

Any translocation efforts will include a comprehensive evaluation plan to document survival, movement, growth, diseases, and reproductive activities. The IDFG will consult with state fish and wildlife agencies (Oregon, Washington) and the Nez Perce Tribe if donor fish are identified from river reaches along shared state boundaries.

Conservation Aquaculture

Conservation of wild, self-sustaining populations of white sturgeon is top priority and Core Conservation Populations will be strictly managed for natural recruitment. The IDFG will not stock, nor will it permit other entities to stock hatchery-reared white sturgeon into Core Conservation Populations. In reaches where natural recruitment is absent or inadequate, hatchery supplementation is one management option to maintain population abundance and diversity and provide fishing opportunity. Hatchery-reared white sturgeon were stocked in the late 1980s on an experimental basis in several Snake River reaches. White sturgeon culture techniques are well developed and released hatchery fish appear to survive and grow at rates comparable to wild fish. One concern with hatchery supplementation is the relatively low number of broodstock fish typically available for hatchery production. Most of the hatchery offspring in a given year are siblings or half-siblings, and high stocking rates would result in populations with relatively little genetic variation. The long-term genetic risks of hatchery supplementation will need to be carefully weighed against the shorter-term risks of population collapse. Any future supplementation will only involve Snake River F1 generation fish. As with other management alternatives, supplementation will be evaluated on a reach-by-reach basis, and any supplementation program will include broodstock (genetic) objectives and an evaluation component to monitor survival, movement, and growth of stocked fish.

A conservation aquaculture program was proposed by Idaho Power Company as part of their White Sturgeon Conservation Plan (Idaho Power Company 2005). The IDFG will take a cautious approach to conservation aquaculture for white sturgeon, but will consider such a program where appropriate. The IDFG envisions a conservation aquaculture program involving Idaho Power Company and the College of Southern Idaho, located in Twin Falls, Idaho. A cooperative agreement would have to be developed and signed by the parties prior to development of an aquaculture program for Snake River white sturgeon. The IDFG will consider white sturgeon supplementation only after the following conditions have been met:

- Careful consideration of the impacts on naturally producing populations both locally and in downstream reaches of the Snake and Columbia rivers;
- Available habitat, food sources, hydrological conditions, and water quality have been improved or restored, and
- To the extent possible, hydropower operation constraints and other limiting environmental factors have been addressed.

Before making any decision on an aquaculture program for Snake River white sturgeon, the IDFG will coordinate with the appropriate stakeholders, most notably adjacent state fish and wildlife managers and the Nez Perce Tribe.

Commercial Aquaculture

The IDFG will work with the Idaho Department of Agriculture to monitor commercial aquaculture operations with respect to importing non-native white sturgeon in their hatcheries (e.g., Sacramento River, CA). Sturgeon are regularly purchased by private pond owners for ornamental purposes in the Magic Valley and Southwest regions of the IDFG.

Mortality Monitoring

Anglers and other river recreationists occasionally observe injured or dead white sturgeon in the Snake River or its reservoirs. Assessing the cause of adult mortalities over time will help describe the relative importance of environmental and disease constraints, hydropower impacts, angling-related effects, illegal harvest, and other mortality sources. The IDFG and Idaho Power Company have established protocols for investigating, examining, and collecting appropriate samples from mortalities whenever possible since we cannot investigate all reported sturgeon mortalities. Examinations may range from a simple field necropsy to a more complete physical and pathological assessment.

7.9.5 Needs & Uncertainties

The following challenges and uncertainties need to be addressed for the Upper Snake River white sturgeon management unit:

- Estimates of the percentage of adult hatchery-origin white sturgeon (PIT tagged) to wild adult white sturgeon (non-PIT tagged).
- Need to evaluate entrainment of hatchery-origin white sturgeon into downstream reservoirs.
- A number of uncertainties are associated with a conservation aquaculture program. Of particular concern is downstream drift of stocked fish into core conservation populations and the long-term risks to genetic integrity. Based on past practices of using very few adult broodstock, closely related progeny, and large numbers stocked with documented downstream movement, there is reason for anxiety. That is why the IDFG is proposing conservation aquaculture as a potential tool to be used only after very careful deliberation involving key stakeholders.

8 BASIN-WIDE ASSESSMENT

This chapter compares sturgeon-related programs throughout the region based on management unit summaries presented in the previous chapter. Comparisons are included for 1) program jurisdictions and involvement, 2) assessment and monitoring, 3) limiting factors and threats, 4) goals and objectives, 5) strategies and actions, and 6) needs and uncertainties. Unit-specific information is examined relative to the regional vision, goals and strategies. These examinations are the basis for conclusions and recommendations identified in Chapter 9.

8.1 JURISDICTION/INVOLVEMENT

Sturgeon conservation, management, and mitigation efforts are complicated by the broadly overlapping jurisdictions and interests of governmental agencies and non-governmental entities throughout the region (Table 15).

Table 15. Summary of jurisdiction and/or involvement identified by management unit plan.

	Management Unit								
	LCR	LMCR	UMCR	TUCR	HUCR	KR	LSR	MSR	USR
States/Provinces									
Oregon	●	●	○	--	--	--	--	◑	--
Washington	●	●	●	●	--	--	●	●	--
Idaho	--	--	--	--	--	●	●	●	●
Montana	--	--	--	--	--	●	--	--	--
British Columbia	--	--	--	●	●	●	--	--	--
Tribes									
Yakama	◑	●	●	○	--	--	◑	--	--
Warm Springs	◑	●	●	○	--	--	◑	--	--
Umatilla	○	●	●	○	--	--	●	--	--
Nez Perce	○	◑	◑	○	--	--	●	●	●
Colville	--	--	--	●	--	--	--	--	--
Spokane	--	--	--	●	○	○	--	--	--
Kootenai (Idaho)	--	--	--	◑	◑	●	--	--	--
CCRITFC	--	--	--	--	●	●	--	--	--
Federal									
USFWS	○	○	○	●	○	●	--	--	--
USACE	●	●	◑	●	○	●	--	--	--
BOR	--	●	●	○	--	--	--	--	--
USGS	◑	◑	◑	◑	●	◑	--	--	--
CDFO	--	--	--	●	●	●	--	--	--
Other									
BPA	●	●	●	●	○	●	●	◑	◑
BC hydro	--	--	--	●	●	●	--	--	--
Idaho Power Co	--	--	--	--	--	--	●	●	●
Grant Co PUD	--	--	●	◑	--	--	--	--	--
Chelan Co PUD	--	--	●	◑	--	--	--	--	--
Douglas Co PUD	--	--	●	◑	--	--	--	--	--

● *Active Involvement* ◑ *Limited Invovlement* ○ *Interested Party*

8.2 ASSESSMENT & MONITORING

Assessments of sturgeon status have now been completed at some level for all management units and monitoring efforts are ongoing in many areas (Table 16). The depth and intensity of assessment and monitoring activities varies among management units depending on the level of utilization or concern. The most intensive efforts occur in the KR where the unique population is listed as endangered under the ESA, and in the LCR and LMCR where important fisheries occur.

Population assessments occur at least periodically in all of the management units. The assessments occur more frequently in areas of the LCR, LMCR and KR units, and less frequently in fragmented reaches of the upper Columbia and Snake units. These assessments provide key information on changes in population abundance, distribution, habitat usage, and age structure of white sturgeon in the Columbia River system.

Table 16. Summary of assessment and monitoring information identified by management unit plan.

	Management Unit								
	LCR	LMCR	UMCR	TUCR	HUCR	KR	LSR	MSR	USR
Population									
Abundance & composition	◕	◕	◕	◕	◔	◕	◔	◔	◔
Distribution & movements	◔	◕	◔	◔	◔	◕	◔	◔	◔
Spawning activity	●	●	●	◕	◔	◕	○	○	◔
Juvenile recruitment	◔	◕	◔	◔	◔	◕	○	○	◔
Survival	○	○	○	○	○	◕	○	○	○
Age / growth	◔	◕	◔	◔	◔	○	◔	◔	◔
Maturation	○	◔	○	○	○	○	○	○	○
Genetics/diversity	○	◕	○	○	○	○	--	◔	◔
Fishery									
Harvest numbers	◕	◕	--	--	--	--	◔	◕	◕
Catch rates	◕	◕	--	--	--	--	◔	◕	◕
Effort/Participation	◕	◕	--	--	--	--	◔	◕	◕
Ecosystem									
Food habits	○	○	○	○	○	◔	○	○	○
Food web	○	○	○	○	○	◔	○	○	○
Predators	◔	--	◔	◔	--	◔	○	--	--
Habitat assessment	○	◔	○	○	○	◕	○	○	◔

●	*Comprehensive*
◕	⇩
◔	
○	*Limited*

Exploitation rates on white sturgeon are estimated annually for commercial and recreational fisheries in the LCR, LMCR and in Snake River management units. While this information provides insight into the status of different subpopulations and helps regulate fisheries, the actual exploitation rates on white surgeon remain unknown. This uncertainty reflects the limited information on size and structure of individual populations, and the level of delayed mortality associated with released fish and removals outside the basin.

Assessment and monitoring of ecosystem conditions occur periodically in all of the management units. These activities, which are most frequent in the KR unit, are providing critical information on the availability of spatial and seasonal white sturgeon habitats in different areas. The information is being used to assess habitat conditions and/or flow limitations, and the effects of these limitations on carrying capacity.

These efforts have contributed a fundamental understanding of the biology, population dynamics, and habitat requirements of this unique species. They have supplied key insight on the status of the different subpopulations, and the life stages and factors that limit production. The efforts have also provided a firm scientific foundation for regulating fisheries, and focused actions to protect, mitigate and restore the subpopulations. Key results include:

- Periodic population assessments, conducted in all of the management units, supply key information on changes in population abundance, condition, growth and distribution.
- Habitat assessments, occurring in all Columbia River management units, are characterizing the availability of spatial and seasonal white sturgeon habitats, and providing critical information on carrying capacity in fragmented reaches.
- Age-0 indexing and juvenile recruitment monitoring, which occurs in most management units, is helping managers understand why natural recruitment is inconsistent or failing among most inland white sturgeon populations, and how recruitment might be increased.
- Genetic assessments and monitoring, occurring in all of the management units except the lower Snake River, contribute critical information on genotypic frequencies within the subpopulations, and a baseline for tracking changes that may occur.
- Translocation of white sturgeon from one reach to another, presently conducted in reaches of the mid-Columbia and Snake Rivers, have demonstrated the potential for increasing abundance and productivity in areas where habitat conditions are limited.
- Evaluations of hatchery supplementation and conservation aquaculture are occurring in several impounded upper Columbia subpopulations and the Kootenai River, and recently in parts of the Snake River on a limited basis. These evaluations have shown that the hatchery-produced sturgeon can survive to adulthood and contribute to fisheries and spawning populations, particularly in depressed populations.

8.3 Limiting Factors & Threats

A variety of limiting and factors and threats have been identified for sturgeon populations throughout the basin (Table 17). The most pervasive factors include habitat fragmentation, local habitat conditions in reservoir and river segments where subpopulations are isolated, and direct or indirect effects of regulated river discharge.

Other limiting factors impacting sturgeon populations are often specific to conditions in a particular management unit. Local water quality issues, including water temperatures and contaminants, affect sturgeon populations in various reaches. Changes in fish communities, and resulting predation and competition, also affect individual sturgeon populations, especially in the upper Columbia and lower Snake reservoirs.

Specific effects if climate change, and how white sturgeon would respond to those changes, are not well understood. Rising water temperatures, lower summer flows, and reduced rearing habitat and food availability due to climate change could negatively affect the populations.

Table 17. Summary of limiting factors and threats identified by management unit plan.

	Management Unit								
	LCR	LMCR	UMCR	TUCR	HUCR	KR	LSR	MSR	USR
Habitat fragmentation	◑	●	●	●	●	●	●	●	●
Habitat diversity / quantity	◑	◑	◑	◑	○	◑	○	○	○
Floodplain connectivity	●	○	◑	◑	○	●	◑	○	○
Flow & flow variation	●	●	◑	●	●	●	●	●	●
Direct hydrosystem mortality	◑	○	○	○	○	○	○	○	○
Water quality	○	○	◑	○	○	○	○	◑	○
Contaminants	○	○	○	○	○	○	○	○	○
Predation	●	○	◑	◑	○	◑	○	--	○
Competition	○	○	○	○	○	◑	○	○	○
Prey base / productivity	◑	◑	◑	◑	◑	●	◑	◑	◑
Exploitation	◑	◑	--	--	--	--	○	○	◑
Climate	--	--	--	--	--	--	--	--	--

● *Primary Factor* ◑ *Secondary Factor* ○ *Related Factor*

8.4 Goals, Objectives & Targets

Existing management unit plans variously define goals, objectives and targets for sturgeon conservation, use, and information at different levels of specificity (Table 18). Management direction for white sturgeon within the difference management units is tailored to the specific circumstances in the area, and the responsibilities and mandates that guide the participating entities.

All of the existing management plans aim to improve and conserve viable sturgeon populations in the different units. With the exception of the LSR and MSR, the plans provide specific targets for sturgeon abundance. Most direction in the plans for conserving the populations is defined in qualitative terms. This reflects the large degree of uncertainty that remains regarding the abundance, distribution and characteristics of existing populations and the carrying capacity of different, often fragmented, habitat areas. Plans for subpopulations in the mid and upper Columbia, Kootenai and parts of the Snake River provide direction for use of translocation, hatchery supplementation, conservation aquaculture and other means to help conserve the populations.

Table 18. Summary of goals and objectives identified by management unit plan.

	Management Unit								
	LCR	LMCR	UMCR	TUCR	HUCR	KR	LSR	MSR	USR
Conservation									
Viability/persistence	●	◑	◑	◑	◑	●	◑	●	◑
Natural production	●	●	◑	◑	◑	●	◑	◑	◑
Temporal components	◑	●	●	●	●	●	--	●	●
Abundance targets	●	●	●	●	●	●	○	◑	●
Recruitment	●	◑	◑	◑	◑	◑	--	◑	◑
Population trends	●	◑	◑	◑	◑	◑	--	◑	◑
Size/age structure	●	◑	◑	◑	◑	◑	--	◑	◑
Spatial structure	●	◑	●	●	●	◑	--	◑	◑
Genetic diversity	◑	◑	◑	◑	◑	◑	--	◑	◑
Use									
Fishery opportunity	●	◑	◑	◑	◑	○	◑	●	◑
Fishery harvest	●	●	◑	◑	◑	○	◑	●	◑
Ecosystem									
Function	○	○	○	--	○	◑	--	◑	○
Information									
Status assessment	◑	◑	◑	◑	◑	●	◑	◑	◑
Limiting factor identification	◑	◑	◑	◑	◑	◑	◑	◑	◑
Measure identification	◑	◑	◑	◑	◑	◑	◑	◑	◑

● Quantitative ◑ Qualitative ○ Referenced / Inferred

Existing management plans call for the continuation or restoration of harvest opportunities for white sturgeon in various reservoirs or reaches. In areas where harvest has been curtailed to protect a struggling sturgeon population, such as in the KR and upper Columbia management units, goals to provide harvest opportunities are secondary to ensuring population viability.

Plans for all of the white sturgeon management units describe objectives to support viable, diverse populations. Only the KR management unit provides specific direction for ecosystem restoration; however, direction in other plans to reestablish viable, naturally reproducing populations infers that ecosystem functions will be provided.

All existing management plans call for further work to assess population status and identify critical limiting factors and measures to address them. Plan goals and objectives continue monitoring activities and aim to refine existing measures to better address limiting factors.

8.5 Strategies & Actions

Specific strategies and actions have been identified by the various management unit plans but implementation of sturgeon measures has been uneven (Table 19). Relatively simple measures such as fishery regulation has occurred but significant habitat or flow actions have rarely been undertaken. Because of the large-scale of riverine sturgeon habitats, large-scale efforts are required and costs have been difficult to justify given uncertain benefits of many habitat and flow-related alternatives.

Habitat reconnection efforts have been limited to several years of experimental transplants from the LCR to LMCR reservoirs, and collection and transport of small numbers of fish among USR river segments where natural production does and does not occur. Volitional passage measures are not currently being implemented due to uncertain benefits, costs, and the potential for negative impacts on sturgeon or salmonids.

Significant habitat restoration efforts designed to benefit sturgeon have been implemented only in the TUCR and KR. Experimental introductions of spawning substrate have occurred in the TUCR. Channel and riparian restoration efforts are underway in the Kootenai system in an attempt to encourage upstream passage of sturgeon into suitable spawning areas. Substrate enhancement in current spawning areas of the Kootenai is also planned.

While regulated river discharge has been identified or is suspected of contributing to reduced natural recruitment in many areas, dedicated flow management has been implemented for sturgeon only in the Kootenai River. Salmon flow measures in the lower Columbia and Snake rivers have not been effectively related to measurable effects on sturgeon recruitment (*Tom Rien, Oregon Department of Fish and Wildlife, personal communication*). Temperature management has also been undertaken for Kootenai sturgeon utilizing different draft elevations at Libby Dam. Operational measures have also been undertaken at lower Columbia River dams to reduce direct mortality of sturgeon during dewatering of turbine draft tubes and fishways for maintenance.

Table 19. Summary of strategies and actions identified by management unit plan.

Strategy, *action*	Management Unit								
	LCR	LMCR	UMCR	TUCR	HUCR	KR	LSR	MSR	USR
Habitat reconnection									
Juvenile passage	--	--	--	--	--	--	--	--	--
Adult passage	--	--	--	--	--	--	--	--	--
Transplants	--	◑	--	--	--	--	--	--	◑
Habitat restoration									
Substrate enhancement	--	--	--	●	--	◔	--	--	--
Channel/Riparian	--	--	--	--	--	●	--	--	--
Hydro system									
Flow management	--	--	--	--	--	●	--	--	--
Temperature management	--	--	--	--	--	●	--	--	--
Facility mortality	◑	◑	--	--	--	--	--	--	--
Entrainment									
Contaminants									
Evaluations									
Point source control	◕	◕	◕	◕	◕	◕	◕	◕	◕
Remediation	◕	--	--	○	--	--	--	--	--
Hatcheries									
Conservation	--	--	--	●	◔	●	--	--	--
Mitigation/Supplementatio	--	○	●	--	--	--	○	--	--
Research									
Ecological									
Predator management	◑	--	--	--	--	--	--	--	--
Nutrient augmentation	--	--	--	--	--	◕	--	--	--
Fishery									
Regulated harvest	●	●	--	--	--	--	●	--	--
Catch & release only	--	--	●	--	--	--	●	●	●
Closure	--	--	--	●	●	●	--	--	--
Enforcement	◕	◕	◕	◕	◕	◕	◕	◕	◕

● *1 = Substantial actions have been completed or are ongoing for the benefit of sturgeon.*
◕ *2 = Demonstrable sturgeon benefits are likely to result from actions implemented for broader purposes.*
◑ *3 = Limited actions have been implemented and are expected to benefit sturgeon.*
◔ *4 = Actions are planned and likely to be implemented with potential benefits for sturgeon.*
○ *5 = Actions have been identified but implementation schedules and commitments have not been established.*

Contaminants are suspected of posing risk to sturgeon, particularly in heavily-impacted areas such as portions of the LCR and TUCR. Sturgeon are likely to benefit from systemic efforts to remediate contaminants.

Sturgeon hatchery programs are increasingly being considered for sturgeon following the development of effective programs in the Kootenai and Transboundary upper Columbia. Conservation aquaculture programs in these areas were undertaken as emergency measures in response to chronic natural recruitment failures. Hatchery efforts have since been extended into the UMCR as mitigation for hydropower impacts on local populations. Similar efforts are currently being contemplated or planned for several LMCR and LSR reservoirs.

While ecological limitations on sturgeon have been widely identified, related actions have generally been limited to sea lion management in the lower Columbia River and nutrient augmentation in Kootenay Lake and the Kootenai River. Neither of these actions was implemented primarily to address sturgeon concerns but both are likely to prove beneficial to sturgeon.

Fishery restrictions have been adopted for sturgeon in all management units to regulate harvest or impacts consistent with subpopulation status. Limited harvest is restricted to the LCR, LMCR and LSR management units. Other areas are either closed or limited to catch-and-release of sturgeon. Fishery enforcement efforts in all areas aim to limit illegal harvest of sturgeon as well as other fish resources.

8.6 Research Needs & Critical Uncertainties

Over the last 25 years, white sturgeon subpopulations across the region have been the subject of extensive research, assessment, and management efforts. Research and assessment efforts have contributed a fundamental understanding of the biology, population dynamics, and habitat requirements of this unique species. They have supplied key insight on the status of the different subpopulations, and the life stages and factors that limit production. The efforts have also provided a firm scientific foundation for regulating fisheries, and focused actions to protect, mitigate and restore the subpopulations. Work has included:

- Periodic population assessments, conducted in all of the management units, supply key information on changes in population abundance, condition, growth and distribution. They allow managers to evaluate survival rates of hatchery fish as compared to those observed in wild sturgeon populations.
- Habitat assessments, occurring in all Columbia River management units, are characterizing the availability of spatial and seasonal white sturgeon habitats, and providing critical information on carrying capacity in fragmented reaches.
- Age-0 indexing and juvenile recruitment monitoring, which occurs in most management units, is helping managers understand why natural recruitment is inconsistent or failing among most inland white sturgeon populations, and how recruitment might be increased.
- Genetic assessments and monitoring, occurring in all of the management units except the lower Snake River, contribute critical information on genotypic frequencies within the subpopulations, and a baseline for tracking changes that may occur.
- Translocation of white sturgeon from one reach to another, presently conducted in reaches of the mid-Columbia and Snake Rivers, increase abundance and productivity in areas where habitat conditions are limited.
- Increased production through hatchery supplementation and conservation aquaculture is occurring in several impounded upper Columbia subpopulations and the Kootenai

River, and recently in parts of the Snake River on a limited basis. Evaluations show that the hatchery-produced sturgeon can survive to adulthood and contribute to fisheries and spawning populations, particularly in depressed populations.

Much remains unknown regarding the abundance and productivity of the various Columbia and Snake white sturgeon populations, and the habitats they rely on (Table 20). Assessments to determine the effectiveness of actions to improve flows, habitat conditions and passage, and increase sturgeon production through hatchery use continue to be research priorities across the units. Many of these assessments are area-specific efforts tailored to the individual circumstances of the area. Remaining uncertainties regarding sturgeon behavior and recruitment and existing habitat and/or flow limitations —and the effects of these conditions on carrying capacity, spawning success, recruitment and sturgeon viability—limit our ability to manage and improve white sturgeon populations across the Columbia River basin. Efforts to improve sturgeon production in several of the different management units face similar issues and unknowns.

Table 20. Summary of research needs and/or critical uncertainties identified by management unit plans.

	Management Unit								
	LCR	LMCR	UMCR	TUCR	HUCR	KR	LSR	MSR	USR
Assessment									
Population Status &Trends	◑	◑	◑	◑	◑	◑	◑	◑	◑
Habitat Status & Use	◑	◑	◑	◑	◑	◑	◑	◑	◑
Distribution & Movement	◑	◑	◑	◑	◑	◑	◑	◑	◑
Population dynamics	◑	◑	◑	◑	◑	◑	◑	◑	◑
Genetics	◑	◑	○	◑	◑	◑	◑	◑	◑
Factors & Threats									
Recruitment limitation	◑	◑	◑	◑	◑	◑	◑	◑	◑
Production capacity	◑	◑	◑	◑	◑	◑	◑	◑	◑
Species interactions	○	○	○	●	●	○	●	○	○
Parasitism/disease	○	○	○	○	○	○	○	○	○
Action effectiveness									
Flow measures	●	◑	◑	◑	◑	◑	◑	◑	◑
Habitat restoration	○	○	○	○	○	●	○	○	○
Hatchery risks	○	◑	◑	◑	◑	◑	◑	◑	◑
Passage	--	◑	◑	◑	◑	○	◑	◑	◑

● Critical constraint / gap for unit
◑ Critical constraint / gap across units
○ Potential constraint / gap for unit

9 FINDINGS

The following conclusions and recommendations were synthesized from a review of the information presented in this document. These findings represent the expert judgment of the individuals on the framework planning team and may or may not reflect the policies of their respective agencies.

9.1 CONCLUSIONS

1. ***Sturgeon program efforts to date have effectively documented biology, status and limiting factors throughout the region but are not sufficient to achieve conservation, recovery or mitigation goals identified for white sturgeon by this framework.***

   Extensive investments have been made by the region to evaluate sturgeon status and investigate limiting factors. These efforts have produced tremendous advances in our knowledge of white sturgeon in the last two decades. More limited investments have been made in specific actions designed to conserve, recover, or mitigate for historical sturgeon declines. As a result, current populations are generally stable at low levels or continue to decline. The most intensive conservation and recovery efforts have been focused on the endangered Kootenai population. In the Kootenai, conservation aquaculture has temporarily forestalled extinction but recovery is nowhere in sight. Much more limited actions have been implemented for sturgeon in other areas. Nowhere have efforts successfully mitigated for lost fishery opportunities resulting from widespread habitat impacts. Both conservation and use are essential elements of a comprehensive regional vision for white sturgeon.

2. ***White sturgeon distribution, abundance, and productivity throughout the Columbia and Snake river basins are severely limited by habitat changes, particularly those associated with hydropower system construction and operation.***

   Effects of population fragmentation and habitat limitations on impounded subpopulations are well documented throughout the region. Historical population declines were driven by overfishing but sturgeon recovery was subsequently limited by hydropower development and operation. As fisheries were closed or regulated, sturgeon populations increased and stabilized in areas where conditions were suitable to complete the entire life cycle. Where habitat does not support natural recruitment, only small, often-declining remnant subpopulations exist. Historical levels of productivity and use have not been achieved in any area due to continuing habitat limitations.

3. ***Large areas of suitable sturgeon habitat remain throughout most of the historical range upstream from Bonneville Dam but use is currently limited by widespread passage and natural recruitment problems.***

   Most of the basin continues to provide favorable conditions for sturgeon growth, survival and maturation from the juvenile to adult life stages. Subpopulations are currently failing in somewhere during the incubation, early life history or young of the year life stages which appear to require very specific combinations of conditions that are rarely met in today's impounded and regulated system. The lack of effective sturgeon passage prevents sturgeon from redistributing among favorable habitats. However, when favorable habitats have been effectively seeded, substantial numbers of white sturgeon have been produced throughout the system. Thus, remaining habitats provide a significant opportunity for sturgeon improvements.

4. ***Lack of upstream passage also impacts productivity of the unimpounded white sturgeon subpopulation downstream from Bonneville Dam.***

   Fragmentation of the historical riverine ecosystem has impacted sturgeon both above and below Bonneville Dam. Until the late 1990s, the unimpounded subpopulation in the lower Columbia below Bonneville Dam was in a long-term increasing trend and supported productive fishery opportunities. However, productivity of this population has recently declined and use is being severely curtailed. Large numbers of sturgeon remain in the population but future declines are likely due to reduced levels of recruitment. The cause of this decline is unclear but a leading candidate is increased predation by seals and sea lions which have recolonized the lower river in significant numbers over the last decade. This predation reduces survival to adulthood and also appears to be disrupting spawning success. Where white sturgeon could historically migrate upstream past rapids to escape this predation pressure to find safe spawning and rearing environments, these upstream movements are now prevented by Bonneville Dam. Even if sturgeon could be effectively passed upstream, they would now find most historical spawning habitat inundated by reservoirs.

5. ***Some opportunities for sturgeon passage improvements exist but benefits are likely to be limited by habitat-related natural recruitment problems in most areas.***

   Passage benefits that increase connectivity can, in some cases, increase gene flow, productivity, and fishery opportunity. However, unintended consequences must be given consideration as they can reduce benefits or prove detrimental. Modeling of upper Snake River populations demonstrated that passage benefits depend on the relative rates of upstream and downstream movements and population productivity in upstream and downstream areas. Many impounded river sections contain habitat that is underutilized by sturgeon due to poor natural recruitment. Net productivity might be improved by providing passage of juvenile and subadult sturgeon into underutilized areas. However, increased upstream passage could be detrimental to net production if adults move from favorable into unfavorable areas. Attempts to improve upstream or downstream passage of sturgeon at dams also risks confounding salmon and steelhead passage.

6. ***Natural recruitment and productivity of white sturgeon has been widely related to normative river conditions including free-flowing reaches and high spring flows but sturgeon-specific hydro system operations have not been widely considered or implemented in the Columbia Basin. The limited hydro measures implemented for sturgeon in some areas have produced marginal benefits at best.***

   The most productive sturgeon subpopulations are currently found in river segments that continue to provide diverse habitats and free-flowing conditions. These include the lower Columbia downstream from Bonneville Dam, and Hells Canyon in the Snake River. Some impounded segments including Bonneville and The Dalles reservoirs in the Columbia and the Bliss reach in the Snake continue to provide significant natural recruitment in some years because favorable habitat conditions still exist. Recruitment in many impounded areas has been positively correlated with high annual discharge during spring. It remains unclear whether smaller scale operational measures can produce similar sturgeon recruitment benefits to those produced by large scale annual patterns. Except in the Kootenai, flow measures have not been implemented for sturgeon due to related costs and competing demands. Experimental flow measures have been implemented in the Kootenai River in an attempt to stimulate natural spawning but no significant improvements were observed in response to measures at the scale they were implemented. Sturgeon might be expected to benefit from flow and dam operational measures being implemented for salmon and steelhead. However, the marginal benefits of those actions for sturgeon are unknown.

7. ***Site-specific habitat measures such as substrate enhancement or channel restoration might be viable alternatives for improving natural recruitment in some areas but benefits and cost-effectiveness remain uncertain.***

   Site-specific habitat measures have not been widely considered for sturgeon throughout the basin owing to uncertain benefits and the difficulty of implementation in a large mainstem river system. Habitat measures are being explored in limited areas of the upper basin including the Kootenai and Transboundary upper Columbia. An ambitious habitat restoration effort has been initiated in the Kootenai River utilizing channel and riparian restoration in an attempt to restore functional habitat processes. Substrate introduction into the H. L. Keenleyside tailrace is being evaluated to determine if lack of suitable substrate currently limits successful spawning and recruitment of the Transboundary population. Similar efforts are being contemplated in the meander reach of the Kootenai River where sturgeon are currently spawning over unsuitable sand substrate. Benefits of these actions remain to be determined.

8. ***Careful use of sturgeon hatcheries has the potential to help perpetuate declining wild populations and mitigate for lost natural production in many impounded areas but aquaculture should be regarded as a stop-gap or interim strategy while other alternatives continue to be explored.***

   In the absence of a clear path to restoration of natural recruitment or a commitment to implementing and evaluating large scale hydro-related actions likely to be required, aquaculture is a realistic alternative for partially meeting some sturgeon goals. In the Kootenai and upper Columbia, conservation aquaculture programs are being used to preserve declining populations and buy time for the identification and implementation of habitat-based measures to restore natural recruitment. In the upper mid-Columbia reservoirs, a hatchery program is being developed under FERC license agreements to mitigate for the failure of natural production in a series of PUD reservoirs. Similar hatchery measures are also being contemplated by Columbia River treaty tribes to mitigate for lost fishery production in lower mid-Columbia reservoirs. The basin's experience with salmon hatcheries has highlighted the risks to wild populations associated with hatchery impacts. At the same time, potential benefits can substantially outweigh risks in many areas where natural production is limited and conservation aquaculture programs in the upper basin have identified effective risk management practices.

9. ***Experimental implementation and evaluation of action effectiveness of a combination of passage, system operation, habitat restoration, and hatchery alternatives provides the best prospects for meeting sturgeon conservation, restoration and mitigation goals throughout the basin.***

   Most work to date has focused on biological research and stock assessment. This work has identified factors limiting specific populations and potential alternatives for ameliorating these limiting factors. Additional research questions can always be identified. In the case of sturgeon, many of these revolve around recruitment failure mechanisms, ecosystem limitations, and ecological interactions. However, significant improvements in sturgeon status and use will require substantive actions to address current limitations. Because potential benefits of specific actions remain somewhat uncertain,

10. ***Sturgeon planning, coordination and project implementation needs within most management units are effectively served by existing groups.***

    Sturgeon projects and activities within different Columbia and Snake River management units are already underway, and reflect the responsibilities and authorities of the appropriate jurisdictions. The objectives and strategies directing these various sturgeon projects are tailored to the specific circumstances within each management unit, and participating entities already support significant consultation and coordination among themselves as part of their normal processes. A one-size fits all approach to sturgeon does not work for every management unit due to the specifics of each subpopulation, conditions and involvement. The implementation framework is already in place to move forward with sturgeon conservation, recovery and mitigation efforts throughout the region where resources are adequate for action implementation.

9.2 CRITICAL UNCERTAINTIES

Regional sturgeon data gaps were considered at the 2012 white sturgeon workshop (Beamesderfer et al. 2012). Participants identified and prioritized five overarching data gaps: 1) mechanisms of natural recruitment failure, 2) genetic stock structure, 3) habitat carrying capacity, 4) critical habitat requirements including flows, and 5) fish passage/connectivity benefits.

1. Mechanisms of Natural Recruitment Failure

Participants at the 2012 workshop highlighted the need for a better understanding of the mechanisms of recruitment failures across the region. Factors limiting natural recruitment were also discussed at the 2011 sturgeon workshop. Sporadic or failing natural recruitment is characteristic of impounded sturgeon populations throughout the basin. However, substantial uncertainties remain in our understanding of factors limiting sturgeon reproduction and recruitment, despite more than a quarter century of research. More significantly, avenues and prospects for improvement remain unclear.

Productivity of sturgeon downstream from Bonneville Dam is much greater than in upstream areas where dam construction has fragmented the river and sturgeon into a series of semi-isolated segments where conditions are no longer optimal to support the fish during different life stages. Research shows that white sturgeon populations in reservoirs above the dams continue to spawn—with substantial spawning activity occurring in some reservoirs, including Bonneville, The Dalles and John Day—but reproduction is often unsuccessful.

Participants at the 2012 workshop determined that recruitment is likely much greater is some areas than in others due to differences in: 1) habitat complexity, quantity, and quality; 2) hydraulic or operation effects of flow; 3) habitat connectivity; and 4) normal river functions. The participants also identified predators and water quality as likely factors. Differences in prey availability, management intensity, density-related factors, stress effects, low spawning stock numbers, and effects of conflicting mandates were also identified as potential factors, although with a lower degree of certainty in effect.

Workshop participants also examined why natural recruitment is inconsistent or falling among most inland populations. They concluded with a high degree of certainty that this is due to: 1) low diversity, 2) lack of adults, and 2) flow levels that were either too low or not the right type or time. They also identified predation as a likely factor. Reservoir length and habitat simplification, narrower temperature windows, and reductions in food productivity or access were also identified as potential factors, although with a lower degree of certainty in effect.

Workshop participants also examined the likelihood of increasing natural recruitment. They concluded that it will likely vary across geography and scale, higher in some areas than in others. They also determined that broodstock limitations may be a factor, and that possible solutions may interact with salmonid management. It was also apparent that prospects may be better in areas with larger, more diverse habitats and populations lower in the system supported by downstream drift and better food resources.

2. Genetic Population Structure

Understanding historical and current genetic population structure is one key to developing a comprehensive and coordinated regional framework. Genetics are an important consideration in addressing specific sturgeon issues in different portions of the Columbia and Snake River basin. An ongoing issue throughout the upper basin is the potential for "genetic swamping" of the remaining wild sturgeon by those produced and stocked from the hatchery. Genetic population structure can have important management implications, particularly for hatchery activities (broodstock selection, effective population sizes, and mating protocols). Additional information is needed on apparent genetic structure within Columbia Basin (i.e., what we have to work with today).

3. Habitat Carrying Capacity

Today, not only are many white sturgeon populations isolated between dams, but the availability and suitability of habitat existing in a reach may restrict sturgeon production. Presently, much remains unknown regarding existing habitat and/or flow limitations, and the effect of these limitations on carrying capacity, spawning success, age-0 survival, etc. Efforts to improve sturgeon production in several of the different management units face similar issues and unknowns.

Poor understanding regarding the productivity of different areas and impoundments to produce white sturgeon makes it difficult for managers to establish realistic population objectives, and to develop measures and programs to meet those objectives. It remains unclear whether the fragmented reservoir habitats can support sizeable, sustainable harvest of sturgeon.

Sturgeon programs throughout the basin have been wrestling with this question with varying degrees of success. Participants in the 2011 Mid-Columbia White Sturgeon Workshop determined that a combined approach would be most effective in defining population objectives consistent with system carrying capacity. An empirical, experimental, adaptive management approach was widely recognized as the most preferable approach to this question for the long term. Participants also found that inferences from information on food webs and trophic dynamics can also be an informative tool. Population models can also be useful to establish ballpark numbers for subsequent empirical analysis.

4. Critical Habitat Characteristics Including Flows

The relationship between recruitment failure and habitat conditions is poorly understood. It is particularly unclear whether natural recruitment can be improved by operational changes in water management. Annual stream discharge has been positively correlated with recruitment success in some areas on the basin. However, similar correlations have not been identified for smaller scale differences in flow or dam operations that might realistically be considered for implementation. Implementation of experimental flow measures for sturgeon have largely been limited to the Kootenai River but this effort has not produced desired results at the flow levels that have been tested.

5. Sturgeon Passage Benefits and Risks

While there are many potential benefits from providing sturgeon passage in the Columbia and Snake Rivers, there are also risks that need to be examined and considered before passage is improved. Many of these risks are related to uncertainty and poor understanding of sturgeon movement, behavior and recruitment, and to increased management complexity. There are still many uncertainties to examine surrounding movement and behavior of white sturgeon that could have implications for passage.

9.3 RESEARCH NEEDS

9.3.1 Stock Assessment

Tools

1.1. Develop improved methods to characterize individual growth of white sturgeon throughout their life cycle and incorporate these into population forecasts and viability assessments.

1.2. Identify and evaluate traditional and novel capture and/or non-capture population abundance estimate designs for juvenile, sub-adult, and adult white sturgeon.

1.3. Evaluate utility of annual effective female population size estimates using nuclear DNA.

Adult abundance

1.4. Develop a white sturgeon stock-recruitment relationship or other production metric that is capable of relating the size of the adult population to recruitment of the number of age-1 juveniles, or to recruitment of the number of sub-adults and adults that comprise the age/size range of the recreationally and commercially harvestable portion of the population.

1.5. Monitor adult female population size and annual recruitment to sub-adult life stage.

Mortality

1.6. Assess the current total mortality level for lower Columbia River white sturgeon.

1.7. Identify and assess subcomponents associated with total white sturgeon mortality within the lower Columbia River.

1.8. Investigate the utility of PIT tags and tagging and novel tag detection technologies for generating survival estimates based on year to year recaptures of white sturgeon.

1.9. Assess river-wide white sturgeon losses to pinniped predation.

1.10. Identify the periodicity and assess magnitude of stress induced reproduction failures related to both catch-and-release fisheries and failed pinniped predation events.

Productivity

1.11. Index annual levels of, and variation in, white sturgeon recruitment in spawning areas of the Columbia River Basin. Correlate age-0 indexing data with relevant measures of annual spawning conditions.

1.12. Using genetic tools estimate spawner contributions to juvenile white sturgeon multi-year cohorts on a decadal basis.

1.13. Monitor spawning and rearing conditions and available habitat via water releases at mainstem dams and spawning periodicity through mark and recapture maturity work; ensure spawning success and recruitment to age 1 by optimizing water releases and through continued time and area management of sport and commercial fisheries in the Columbia River.

1.14. Conduct white sturgeon stock assessments to monitor size distribution, growth, condition and abundance.

1.15. Conduct research regarding reservoir productivity for Bonneville Reservoir regarding the sturgeon productivity issues characterized by low relative weights and poor growth rates.

9.3.2 Distribution & Habitat Use

1.16. Identify, characterize, catalogue, and monitor spatial and seasonal white sturgeon spawning and rearing habitats.

1.17. Investigate estuarine, tidally influenced freshwater and off-channel shallow water habitat usage by juvenile and sub-adult white sturgeon.

1.18. Identify and assess seasonal and spatial white sturgeon habitat usage of nearshore (to 600 feet) marine habitats and migration corridors.

1.19. Model the impact of past spawning and rearing habitat losses on white sturgeon population dynamics.

1.20. Develop more advanced habitat modeling tools to better quantify the amount of spawning and rearing habitat available.

1.21. Determine marine, estuarine, and freshwater habitat usage in areas downstream from Bonneville Dam. Instrument white sturgeon with acoustic and/or radio transmitters to work in coordination with the Pacific Ocean Shelf Tracking (POST) program and other telemetry receivers to determine marine, estuarine, and freshwater habitat usage; work cooperatively with green sturgeon researchers to maximize receiver systems in coastal waterways.

1.22. Investigate the utility of fin spine microchemistry to analyze interchange of white sturgeon among Columbia River and coastal waterways.

1.23. Investigate the utility of genetic analysis tools for estimating the proportions of Columbia, Sacramento, and Fraser River stocks composing the white sturgeon population within those lower Columbia River waters downstream of Bonneville Dam. If these tools prove useful, analyze the stock composition of white sturgeon that occur within these areas.

1.24. Identify, characterize, catalogue, and monitor spatial and seasonal usage of habitats by larval and sub-yearling white sturgeon from Bonneville Dam downstream to the mouth.

9.3.3 Limiting Factors

Hydro development & operations

1.25. Determine the effects of power peaking operations and load following on white sturgeon spawning behavior and success.

1.26. Evaluate spawning habitat in the transition zones ([a] between Bradford and Cascade Islands, and Tanner Creek; [b] downstream from Tanner Creek) downstream from Bonneville Dam to determine how a range of operations at the dam affect hydraulics in the transition zones and the resulting suitability of spawning habitat.

1.27. Identify, assess, and minimize downstream passage mortality at mainstem dams.

1.28. Evaluate the effect of the proposed construction (e.g. spill training wall) in the tailrace of Bonneville Dam on white sturgeon spawning habitat quantity, quality, and distribution.

1.29. Investigate riparian and off-channel shallow water habitat usage by white sturgeon early life history stages in the Ives and Pierce Island complex downstream of Bonneville Dam and determine potential effects of daily and hourly flow variations associated with power peaking on survival of these early life history stages.

1.30. Investigate how the range of spring/summer flows affects the rate and extent of downstream dispersal of white sturgeon larvae and sub-yearlings in the lower Columbia River, including drift to brackish and saltwater portions of the estuary where fish of these life-stages would not survive.

Habitat Alteration

1.31. Monitor dredging and in-water work to document operational related white sturgeon mortality.

1.32. Assess the effects of dredging and dredge spoil deposition on lower Columbia River aquatic invertebrate communities.

1.33. Identify and assess the effects of gravel extraction, construction, and remediation related dredging activities on lower Columbia River white sturgeon.

1.34. Identify and assess the impacts of in-water construction on white sturgeon in the lower Columbia River.

1.35. Investigate the role of pile rows and similar structures in the proposed lower Columbia River white sturgeon ecology.

1.36. Consider additional analysis or research of larval and juvenile downstream passage and mortality to better understand tradeoffs between upstream and downstream subpopulations.

1.37. Conduct research and coordinate with others doing habitat research on the merits of creating spawning habitat and early rearing habitat in selected tailrace areas.

1.38. Work with partners in modeling the impact of channelization and diking of the lower Columbia River on water velocities and downstream dispersal rates of larvae and sub-yearling white sturgeon.

1.39. Work with partners in modeling theoretical water velocities and downstream dispersal rates of larvae and sub-yearling white sturgeon for the Columbia River upstream to Celilo Falls under pre-impoundment and pre-channelization conditions and evaluate the likelihood of early-aged sturgeon washing to the estuary from historic spawning sites upstream of where Bonneville Dam is located.

Water Quality & Contaminants

1.40. Conduct additional baseline research on the contamination levels in fish and gonads of adult broodstock to determine if contamination is changing and potentially affecting productivity of selected populations.

1.41. Identify and assess the effects of FCRPS operations on water temperatures.

1.42. Identify the effects of low turbidity on white sturgeon recruitment.

1.43. Identify the effects of total dissolved gasses on white sturgeon survival.

1.44. Implement cause and effect studies to determine if pollutants and contaminants affect white sturgeon survival and spawning success.

1.45. Model the effects of changes in a variety of water quality parameters white sturgeon population dynamics.

1.46. Conduct “dose-response” studies to resolve issues surrounding toxins of concern by identifying the specific toxin and contaminant effects on white sturgeon survival and spawning success.

Fishing

1.47. Conduct recreational and commercial fisheries monitoring activities for weight of evidence materials used to evaluate current status as well as trends over time. Information collected should include, but not necessarily be limited to: effort, number of fish of a given size caught and released, average size of catch, and tag recoveries.

1.48. Assess the current fishing mortality levels and evaluate the total mortality level for white sturgeon.

1.49. Identify and assess the magnitude, extent, and effects of illegal harvest on white sturgeon. Include estimates of illegal harvest when evaluating whether target exploitation rates are being met.

1.50. Model the impacts of a variety of harvest regimes, including estimated illegal harvest and post-release mortality from commercial and recreational fishing, on white sturgeon population productivity.

Food Web

1.51. Monitor lamprey and salmon returns to the Columbia River through passage counts, and eulachon returns through a combination of scientific test sampling of adults, and early life history (larval and egg) investigations; support actions aimed at rebuilding those populations towards desired and historic levels.

1.52. Conduct bioenergetics modeling/food web analysis to determine: a) the effects on white sturgeon of a diet consisting of various combinations of native and non-native prey items, and b) how a changing forage base through time might affect the white sturgeon productivity.

1.53. Conduct bioenergetics modeling to determine effects on white sturgeon of operation of the FCRPS and historic loss of habitat caused by development and channel improvements for navigation.

1.54. Conduct an assessment of native invertebrates in Columbia River reaches.

1.55. If declines in native forage species are negatively impacting lower Columbia River white sturgeon, determine population limiting factors for Pacific lampreys, eulachon, and native invertebrates.

Non-Native Species

1.56. Investigate feeding ecology to determine the relative importance of non-native prey items such as American shad and Asian clams to white sturgeon.

1.57. Conduct bioenergetics modeling to determine the effects on white sturgeon of a diet consisting of various combinations of native and non-native prey items.

1.58. Determine if foraging on thiaminase-rich American shad has a negative effect on white sturgeon.

1.59. Investigate inter-specific competition between: juvenile American shad and juvenile white sturgeon; Asian clams and native freshwater mussels; and Mysid shrimp and native amphipods.

Climate Change

1.60. Monitor white sturgeon condition and spawn timing as a possible response to, and as a potential bellwether for, systemic changes Columbia River reaches due to global climate change.

1.61. Model the effects of water temperature increases, changes in the seasonality of the freshet and low elevation run-off, and possible changes in salt-wedge intrusion on white sturgeon spawning success and population dynamics Columbia River waters.

1.62. Monitor and model the effects the above mentioned climate changes on white sturgeon food resources in Columbia River reaches, including the Columbia River mainstem, estuarine, and marine waters.

9.4 CONSERVATION, RESTORATION & MITIGATION RECOMMENDATIONS

The following recommendations reflect a basin-wide perspective. More detailed guidance for specific management areas may be found in area-specific plans which are also summarized in Chapter 7.

Programmatic

1.1. Sturgeon programs and projects throughout the region need to address both conservation/recovery and use/mitigation goals.

1.2. Additional resources will be necessary to meet goals consistent with the regional vision for sturgeon identified by this framework document.

1.3. Include areas above and below Bonneville Dam in a comprehensive treatment of FCRPS effects on white sturgeon.

Passage[5]

1.4. Clarify specific goals and objectives for subpopulations based on current natural recruitment potential, habitat productivity, and limiting factors to provide guidance on potential benefits and risks of increased upstream or downstream passage on a case-by-case basis.

1.5. Include detailed evaluations of costs, benefits and risks of passage improvements relative to other potential strategies including habitat improvement, flow management, fishery regulation and hatchery supplementation in sturgeon mitigation, conservation and restoration plans.

1.6. Consider opportunities for incorporating sturgeon-friendly features in existing fish ladders during future ladder designs and planned modification where consistent with sturgeon population goals and objectives.

1.7. Consider opportunities for non-volitional passage by taking advantage of fish trapped in dewater draft tubes or fish ladders during maintenance. These fish can be released back downstream from dams or transplanted upstream. Fish could also be tagged as a means to gain information on sturgeon behavior and movement in and around dams. This would be cost effective since it occurs with planned maintenance. There is also a need for better communication/coordination with maintenance operations so we can take advantage of these instances as they occur.

1.8. Review current protocols used to prevent fish stranding/mortality during planned maintenance activities (such as dewatering draft tubes) to determine if the level of protection/prevention is adequate and whether improvements could be made. Where appropriate and feasible, improve prevention/control of existing sources of mortality caused by the projects either from dewatering mishaps or blade strikes associated with turbine starts. These include:

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[5] *Passage recommendations were developed at the 2012 regional sturgeon passage workshop.*

a) Enumeration and documentation of operational white sturgeon mortalities.

b) Blocking access to turbine draft tubes during turbine dewatering and other maintenance operations as necessary to minimize and avoid white sturgeon entrainment.

c) Salvage operations for any white sturgeon entrained after emergency turbine dewatering procedures.

d) Minimization of mortality related to the bringing turbines online. For instance, powerhouse upgrades to digital controls would allow "slow roll" starts to be used for all turbine starts throughout the year.

Hydrosystem Operations

1.9. Continue to experimentally evaluate benefits of specific flow measures for sturgeon in areas of acute necessity (such as the Kootenai River).

1.10. Identify and assess potential sturgeon benefits of normative river operations implemented for salmon and steelhead.

1.11. Pursue other opportunities for operational management to improve conditions for natural recruitment of sturgeon where feasible. Operational opportunities may address:

a) Limitations in the quantity, quality, and distribution of spawning and/or rearing habitat as well as adjacent riparian habitat.

b) Water temperatures and dissolved gas supersaturation levels consistent with white sturgeon spawning, incubation, and early life stage development and dispersal criteria.

c) River flows that minimize predation on white sturgeon early life history stages by native and non-native predators.

Other Limiting Factors

1.12. Identify time periods and specific river reaches or areas when certain in-water work activities should be restricted to avoid impacts to sensitive white sturgeon life stages (e.g. spawning, incubation). Implement in-water work and development permits in coordination with appropriate state and federal agencies to minimize, avoid, or mitigate sturgeon impacts.

1.13. Implement experimental habitat restoration measures in appropriate areas where they may be directly related to sturgeon habitat limitations (e.g. substrate and river function limitations identified in the upper Columbia and Kootenai rivers).

Fisheries

1.14. Identify short and long-term fishery expectations and objectives specific to each sturgeon subpopulation consistent with regional mitigation goals for sturgeon use.

1.15. Continue to regulate harvest and fishery impacts to ensure that the population of mature adults is sufficient to sustain significant levels of natural recruitment in areas where suitable conditions exist, based on an effective fishery monitoring program.

1.16. Employ intensive fishery management to optimize use benefits of harvestable subpopulations as a mitigation measure for widespread hydro system impacts.

1.17. Pursue appropriate opportunities to develop meaningfulfisheries in to mitigate for lost productivity in areas where natural recruitment is currently limited and the subpopulation does not represent a unique component of the historical diversity.

1.18. Implement educational and angler awareness programs to inform the public of the consequences of over-harvest of long-lived white sturgeon.

1.19. Provide adequate law enforcement personnel to enforce current laws/regulations that protect white sturgeon and their habitats.

Hatcheries

1.20. Continue to utilize and adaptively manage conservation hatchery programs as interim measures to avoid extinction of unique sturgeon populations.

1.21. Employ hatchery production of sturgeon to supplement other populations where natural recruitment is currently limited.

1.22. Be conservative and responsible in establishing protocols for source populations and numbers of hatchery fish released. Build from ongoing hatchery efforts in other areas.

1.23. Utilize experimental hatchery releases and monitoring to assess ecological factors and population productivity limitations.

1.24. Optimize hatchery production and practices consistent with environmental carrying capacity which will most effectively be identified using an experimentally adaptive approach.

Research, Monitoring & Evaluation

1.25. Integrate status and trends, and action effectiveness monitoring to allow effective adaptive management of future sturgeon programs.

1.26. Need to dedicate some work to assess cross-basin information needs including food habitats, ecological interactions, maturation biology, genetic stock structure, and bioenergetics.

1.27. Additional research, monitoring and evaluation are particularly needed for the unimpounded subpopulation downstream from Bonneville Dam which is essential to the long-term health of the Columbia basin white sturgeon population.

Outreach

1.28. Continue to support state and tribal public involvement processes for outreach, information, and education functions related to sturgeon conservation, management and mitigation in each management unit.

1.29. Facilitate information availability and regional coordination by developing and maintaining a Council web page portraying key sturgeon metrics and links to pertinent resources.

a) Identify and report common metrics that serve as benchmarks for local white sturgeon managers in assessing the response/performance of local populations relative to other areas.

b) These may include: adult abundance, juvenile recruitment, life-stage specific growth and mortality rates, and genetic diversity.

c) Describe assessment protocols and meta-data to assure that comparisons are appropriate.

1.30. Endorse and employ regional and local data management strategies to assure the security, quality and accessibility of white sturgeon data sets.

1.31. Continue to rely on a dispersed data management and sharing system among sturgeon management units for populations that are functionally isolated.

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ACRONYMS AND ABBREVIATIONS

BC MoE	British Columbia Ministry of Environment
BiOp	2000 Federal Columbia River System Biological Opinion
BPA	Bonneville Power Administration
CCT	Colville Confederated Tribes
CCRITFC	Canadian Columbia River Inter-Tribal Fish Commission
CDFO	Canada Dept. of Fisheries and Oceans
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CRFMP	Columbia River Fishery Management Plan
CRITFC	Columbia River Inter-Tribal Fish Commission
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CTWSRO	Confederated Tribes of the Warm Springs Reservation of Oregon
DO	dissolved oxygen
ESA	Endangered Species Act
FERC	Federal Energy Relicensing Commission
FCRPS	Federal Columbia River Power System
FL	fork length
HLK	Hugh L. Keenleyside Dam
IDFG	Idaho Fish and Game
IPC	Idaho Power Company
ISRP	Independent Scientific Review Panel
KTOI	Kootenai Tribe of Idaho
MFWP	Montana Fish, Wildlife & Parks
M&E	Monitoring and evaluation
MSU	Montana State University
mtDNA	mitochondrial DNA
NPCC	Northwest Power and Conservation Council
NPT	Nez Perce Tribe
ODFW	Oregon Department of Fish and Wildlife
PAHs	polyaromatic hydrocarbons
PBDEs	polybrominated diphenyl ether; fire retardant
PCBs	polychlorinated biphenyls
PSMFC	Pacific States Marine Fisheries Commission
PUD	Public Utility District
Rkm	River kilometer
RM	River Mile
SARA	Species At Risk Act
SMTF	Sturgeon Management Task Force
SOR	System Operation Requests
TBD	To be determined
TDG	total dissolved gas

TGP	total gas pressure
TL	total length
TMDL	total maximum daily loads
UCWSRI	Upper Columbia White Sturgeon Recovery Initiative
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WDFW	Washington Department of Fish and Wildlife
WDOE	Washington Department of Ecology
WQAP	Water Quality Attainment Plan
YN	Yakama Indian Nation

GLOSSARY

abiotic factor—non-living chemical and physical factors in the environment that affect organisms and populations inhabiting the environment

Acipenser fulvescens—Scientific name of the lake sturgeon

Acipenser medirostris—Scientific name of the green sturgeon

Acipenser oxyrhynchus—Scientific name of the Atlantic sturgeon

Acipenser transmontanus—Scientific name of the white sturgeon

age-0 indexing activities—Indexing activities at that use small mesh gillnets at standardized sites to determine *relative* reproductive success of white sturgeon; usually conducted in the fall

adult white sturgeon—White sturgeon that are greater than 166 cm FL in length and have reached sexual maturity

allele—Any of the alternative forms of a given gene

allelic frequency—The relative proportion of all alleles of a gene that are of a designated type

Alosa sapidissima—Scientific name of the American shad.

amphipods—Crustaceans with a vertically thin body and one set of legs for jumping or walking and another set for swimming

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.

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

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

benthic—Of or relating to or happening on the bottom under a body of water

bioaccumulation—The process by which substances accumulate in the tissues of living organisms; used especially in regard to toxic substances, such as pesticides, that accumulate via a food chain

biotic factor—The living things present in the environment that shape an ecosystem.

broadcast spawner—An organism that releases eggs or sperm directly into the water column during reproductive activities for external fertilization

broodstock—The group of sexually mature white sturgeon available for breeding

buccal cavity—The oral cavity that opens to the outside at the lips and empties into the throat at the rear; and containing structures for chewing and tasting in higher animals

bycatch—Incidental or unintended catch of non-target species.

Carcharodon carcharias—Scientific name of the great white shark.

chironomid—small two-winged mosquito like fly lacking biting mouth parts; a member of the midge family of insects

chromosome—A threadlike strand of DNA in the cell nucleus that carries the genes in a linear order

chlorinated pesticides—Pesticides that have been shown to be hormone disrupters and cancer causing agents in vertebrates, e.g., DDT

clupeid—A member of the family Clupeidae, the herrings, shads, sardines, etc.

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.

conservation status—A level, for a given biological attribute, that must be avoided if possible which if reached would require significant management actions to alleviate, and a level below which the future persistence of the population becomes unpredictable. This level should not be considered as the lower end of an otherwise healthy population.

Corbicula fluminea—Scientific name of the non-native freshwater Asiatic clam

Corophium—Genus of aquatic invertebrates belonging to the order Amphipoda, members of which are commonly referred to as amphipods

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.

density-dependent—Factors that affect population size that vary with population density, e.g., food availability, predation, or availability of spawning sites

density-independent—Factors that affect population size that do not vary with population density, e.g., water temperature, river flows, or climate change

denticles—Small bony, conical, pointed projections found on the skin of white sturgeon

desired status—The level, for a given biological attribute, that must be met for the goal of the conservation plan to be met; is derived through a combination of historic carrying capacity and societal goals and expectations. It explicitly involves a population segment that is both healthy and harvestable.

diadromous—Fishes that use both marine and freshwater environments

dioxins/furans—Dioxins and furans is the abbreviated or shortname for a family of toxic substances that allshare a similar chemical structure; they are known to be harmful to humans, potentially causing cancer and changing hormone levels

disomy—Containing two sets of chromosomes

distinct population segment—The smallest division of a species allowed to be protected under the U.S. Endangered Species Act

effective female population size—A basic parameter in many population genetics models; essentially the number of breeding females in a population

egg-to-age-1 survival—PVA model parameter that estimates the survival rate of white sturgeon egg to age-1.

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

embryo—An organism in its early stages of development, especially before it has reached a

distinctively recognizable form **embryonic—**Of or relating to an embryo

empirically derived estimate—An estimate derived from field (aka empirical) data, as opposed to estimates derived solely through modeling exercises

Endangered Species Act—Federal legislation that is intended to provide a means to conserve the ecosystems upon which endangered and threatened species depend

Engraulis mordax—Scientific name of the Pacific anchovy

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

eulachon—Pacific Northwest native fish belonging to the family Osmeridae. Common names, depending on geographic location may include (but are not necessarily limited to): smelt, hooligan, oolachon, candlefish, and fathom fish

Eumetopias jubatus—Scientific name of the Steller sea lion

exogenous feeding—Feeding and deriving nutrients from external sources, as opposed to endogenous feeding on a yolk sac

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.

fecund—Producing or capable of producing an abundance of offspring or new growth; fertile

fecundity—The quality or power of producing abundantly; fruitfulness or fertility

federal trust species—All species where the federal government has primary jurisdiction including federally endangered or threatened species, migratory birds, anadromous fish, inter- jurisdictional fish species, and certain marine mammals.

fish tickets—A landings report produced when commercial fishers deliver fish to fish buyers; include information on total fish weight and number of sturgeon delivered

fishing mortality—That component of total mortality that stems from fishing related activities such as harvest, stress induced post release mortality, or any other fishing related factor that causes death of fish

flat-load—Providing constant flow, and electricity generation, through a powerhouse at a hydro- electric facility

follicular atresia—The degeneration and reabsorption of ovarian follicles before they reach maturity; mature eggs are not released

free swimming embryo—The period when a white sturgeon embryo hatches from its egg, yet is still receiving all of its nutrition internally from its yolk sac

freshet—A flood spawned from the spring thaw resulting in snow and ice melt in rivers located in the northern latitudes of North America. A spring freshet can sometimes last several weeks on large river systems, resulting in significant inundation of flood plains as the snow pack melts in the river's watershed.

freshwater amphidromous—Fish that spawn in freshwater but regularly move between freshwater and saltwater to feed; movement to saltwater is not required to complete life cycle

functional extinction.—Small population size below which severe genetic and demographic bottlenecks make recovery unlikely.

gas bubble trauma. Fatal or sublethal fish syndrome resulting from exposure to high levels of dissolved gas in the water, denoted by the acronym GBT.

gene flow—Exchange of genes among populations resulting from either dispersal of gametes or migration of individuals; also called migration

genetic markers—Alleles whose inheritance can be traced through a mating or pedigree

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.

genome—The total complement of genes contained in a cell; commonly used to refer to all genes present in one complete set of chromosomes

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

habitat suitability indices—A numerical index that represents the capacity of a given habitat to support a selected species

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

heterozygosity—The presence of different alleles on one or more genes

homogeneous—Uniform structure or composition throughout, e.g., a genetically homogenous population

hydrograph—A graph of the flow in a river or stream over some period of time

hydrosystem—The series of hydro-electric, flood control, navigation, and irrigation related dams, locks, and canals in the Columbia River

hydrosystem operations—those operations at hydropower facilities that directly affect the flow and route of water and power generation down stream

hydraulic complexity—Areas in the river that through channel complexity (e.g., rocks, islands, etc.) or other means (e.g., river confluence) cause turbulent water flows

hypoxia—Environmental condition when oxygen concentrations fall below the level necessary to sustain most animal life

instantaneous total mortality rate—The force of total combined natural and fishing mortality, often denoted in fisheries management as Z; not to be confused with the number of fish that actually die annually

iteroparous—A reproductive strategy of an organism characterized by reproducing multiple times over the course of its lifetime

juvenile white sturgeon—This life stage begins at age-1 and lasts until sturgeon are able to enter estuarine and marine environments, approximately 96 cm (38 inches) fork length

Lampetra—Genus for Pacific lampreys

larvae—A distinct juvenile form many animals undergo before metamorphosis into adult-like life form; singular is larva

legacy effect—the delayed effect of white sturgeon fishery management actions; because of their longevity, slow growth, and late maturity management actions affecting white sturgeon can take a long time (decades) to fully express themselves

lipid—A group of organic compounds that includes fats, oils, waxes, sterols, and triglycerides, that are insoluble in water, are oily to the touch, and together with carbohydrates and proteins constitute the principal structural material of living cells

loci—The sites or positions of particular genes on a chromosome; singular is locus **l**

longevity—A long duration of individual life; life span, e.g., white sturgeon longevity is thought to approach or exceed 100 years of age

management buffer—A deliberate lowering of a managed exploitation rate from predetermined targets by a set amount with the goal reducing potential risks to exploited populations

maturation—The process of becoming sexually mature

metabolic energy—The amount of energy provided to living cells to perform vital processes and activities

metamorphosis—A marked and abrupt developmental change in the form of an animal occurring after hatching or birth, e.g., caterpillar to butterfly metamorphosis

metapopulation—A group of spatially separated populations of the same species which interact at some level

Micropterus—Genus for black basses such as smallmouth bass

microsatellites—A type of genetic marker based on a short DNA sequence that is present at one or more sites in the genome

mitochondrial—Having to do with mitochondria, which are energy producing cellular organs

natural mortality—That component of total mortality that stems from natural causes such as disease, competition, cannibalism, old age, predation, pollution, or any other natural factor that causes death of fish; may account for total mortality in unexploited fish stocks.

Notorynchus cepedianus—Scientific name of the broadnose sevengill shark.

octoploid—An organism with eight complete sets of identical chromosomes

Oncorhynchus—Genus for Pacific salmon

Oncorhynchus mykiss—Scientific name for steelhead

Oncorhynchus nerka—Scientific name for sockeye salmon

Oncorhynchus tshawytscha—Scientific name for Chinook salmon

osmoregulate—The ability to regulate the pressure associated with different salt concentrations inside and outside the body of an organism

Petersen mark-recapture model—A technique employed to estimate the size of a given population involving two examinations of a population, the first in which target animals and marked, and a second where target animals are recaptured; denoted as N=M*C/R, where N is the population size estimate, M is the number of fish marked in the first pass, C is the number of fish examined for marks in the second pass, and R is the number of examined fish in the second pass that possess a mark

Phoca vitulina—Scientific name for harbor seals

pinniped—Any of a group of 33 species of aquatic, fin-footed mammals including sea lions, seals, and the walrus

piscine—Of**,** relating to, or characteristic of fish

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.

plasma cortisol—A stress hormone found in the blood of animals

ploidy—The number of sets of chromosomes in an animal cell

polychlorinated biphenyls—A type of organic compound known to cause cancer in vertebrates; commonly known by its acronym, PCB

population viability analysis—A species-specific method of risk assessment frequently used in conservation biology traditionally defined as the process that determines the probability that a population will go extinct within a given number of years; commonly referred to by the acronym, PVA

private allele—Alleles unique to a given local population

punctuated interoparity—Repeat spawning cycles with more than one year in between cycles

random genetic drift—Fluctuation in allelic frequency from generation to generation resulting from restricted population size

recruitment—Successful natural reproduction and survival of juvenile fish to a size or age where many are likely to survive contribute to future generations; may also be used to indicate surviving to a specific life stage, e.g., sub-adult

relative weight—A condition factor for fish where by the weight of an individual fish is compared to a standard weight for a fish in the population of the same size; calculated as Wr=W/Ws * 100, where Wr is the calculated relative weight, W is the weight of the fish you are measuring and Ws is the standard weigh of a fish of that length in the population

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.

reproductive periodicity—The period of time between spawning events, e.g., if a white sturgeon female spawned in 2004 and again in 2007, her reproductive periodicity would be 3 years

riverine—Relating to, formed by, or resembling a river

Salmo salar—Scientific name of Atlantic salmon

Sebastes—Genus for Pacific rockfish

Select Area Fisheries—A type of terminal fishery whose location, such as a slough or a bay, allows for rearing, acclimation, release and subsequent harvest of known-stock hatchery-origin salmon with limited impacts on non-local stocks due to geographic separation

significantly different—Statistically speaking, indicates a difference at a certain alpha level (typically = 0.05) of significance; similar statistical meanings may apply to “significant increase” and “significant relationships”

Species at Risk Act—Canadian Federal Species at Risk Act. (Proposed but not adopted) denoted by the acronym SARA.

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

standardized indexing sites—Sites chosen for sampling that are sampled year after year, with a long enough time-series trends can be detected at these sites

stochastic—Random; specifically involving a random variable

sub-adult white sturgeon—The life stage that begins when white sturgeon can enter estuarine and marine environments and ends at sexual maturity

swim up—Dispersal life stage of sturgeon where after absorbing their yolk-sac free swimming embryos leave the bottom and enter the water column where they are transported downstream

Thaleichthys pacificus—Scientific name of the Pacific eulachon

thalweg—The deepest path along the entire length of a river bed in its downward slope, defining its deepest channel

thermal regimes—Usually defined by the mean daily temperatures during the period of time in question

Total maximum daily load (TMDL). 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.

turbine draft tubes—The pipe used for discharging water from a hydro-electric turbine.

vertebrate—A group of animals possessing a segmented spinal column; also includes a few primitive animals in which the backbone is represented by a notochord.

Zalophus californianus—Scientific name of the California sea lion