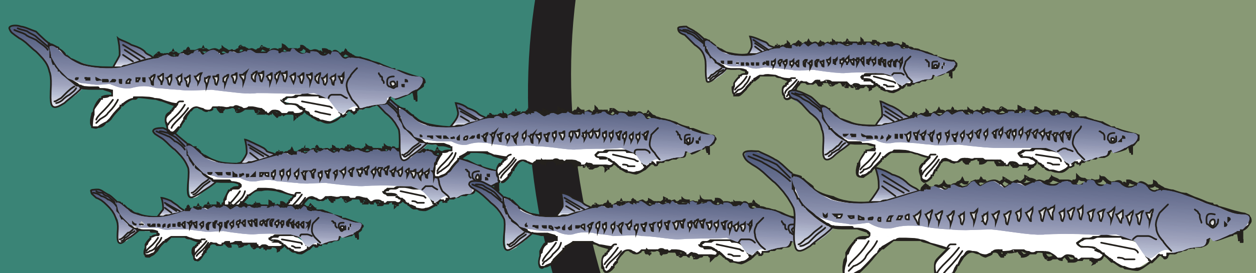
December 2013

Columbia Basin White Sturgeon Planning Framework

Prepared for

The Northwest Power & Conservation Council



PREFACE

This document was prepared at the direction of the *Northwest Power and Conservation Council* (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 requested that a basin-wide sturgeon management Framework be developed through a collaborative effort involving currently funded projects. Although not necessarily representative of all tribal, state and federal managers and other stakeholders involved in white sturgeon activities, 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 development of a basin-wide management framework. 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 agreed to collaborate on this effort and work with the Council to coordinate development of this Framework. 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. However, this Framework also includes ongoing white sturgeon research, monitoring, evaluation, conservation, and management activities in the mid-and Upper Snake, the Upper Columbia reaches in British Columbia, and the Kootenai (y) River in Idaho, Montana, and British Columbia. Thus, all these areas are collectively referred to as the Columbia River Basin as portrayed in this White Sturgeon Framework.

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 Overview

Worldwide, most sturgeon stocks are imperiled and white sturgeon (*Acipenser transmontanus*) in the Columba River Basin are no exception. Sturgeons are particularly sensitive to overharvest and habitat degradation, both of which have reduced abundance and population productivity of most sturgeon species and populations (Birstein et al. 1997; Boreman 1997; Gross et al. 2002). Their longevity, late maturity, and other life history traits have served sturgeons well over evolutionary time; however, given current conditions in altered riverine, estuary, and marine habitats, these traits now present substantial challenges for their recovery (Gross et al. 2002; Anders 2004). Chronic recruitment failure has led to the listing of entire species and population segments of all sturgeon species in North America. White sturgeon are currently listed as endangered in the US and Canada in the Kootenai River and Kootenay Lake systems (USFWS 1994; CDFO 2007).

This Framework Plan reports that of 33 sub-populations of white sturgeon throughout the Columbia basin in the US and British Columbia, 30 (90%) were identified as having natural recruitment of inadequate magnitude and frequency to be sustainable without intervention (Hildebrand and Parsley 2013). Recruitment failure occurs during different life stages in different Basin populations for a variety of reasons (Anders et al. 2002; Parsley et al. 2002; McAdam 2012; Hildebrand and Parsley 2013). While diagnosing specific recruitment failure causes or mechanisms for many populations is difficult and potentially complex, these difficulties may be surpassed by the difficulties associated with resolving these limiting factors in altered large river ecosystems.

Recruitment or year class production can come from natural or hatchery production. While natural production may be preferred, ecological conditions of many altered habitats and the remnant demographic status of most subpopulations suggest at least an interim need for hatchery production to prevent impending extinction of many sub-populations in the Basin. Progress in understanding the likely causes of recruitment failure and potential restoration options has resulted from the combination of laboratory and field studies. Investigations of factors such as the substrate requirements and the various benefits that can result from substrate have provided important contributions to our understanding of sturgeon recovery needs. The need for laboratory studies of basic sturgeon biology is also emphasized to address the many critical uncertainties regarding sturgeon biology (e.g. they are not nearly as well studied as groups of fish such as salmon) and the challenges of implementing experimental studies and remedial management activities in the large river habitats occupied by white sturgeon.

This Framework Plan also identifies five distinct Management Units (MUs) that contain nine distinct Genetic Management Units (GMUs) for Columbia Basin white sturgeon to facilitate and guide coordinated conservation and management activities. Defined as an outcome of a facilitated workshop to develop of this Framework (Beamesderfer et al. 2011), each MU encompasses a discrete section of the basin with common stock characteristics, habitat conditions, limiting factors, management strategies, and jurisdictional boundaries. Genetic

Management Units represent river reaches containing sturgeon with similar genetic characteristics (Drauch Schreier et al. 2013).

Finally, information is provided in this Framework for each of the nine MUs:

1. Agency and entity jurisdiction and managerial involvement
2. Assessment and monitoring information
3. Limiting factors and threats
4. Goals and objectives
5. Research needs/critical uncertainties

This information was gathered from sturgeon management plans, peer-reviewed literature, project, scientific reports, input from the four recent regional workshops on Columbia basin white sturgeon (2009, 2010, 2011, 2013), and from basin sturgeon mangers and researchers Framework review comments on the February 2012 review draft of this Framework.

Figure 2. Large white sturgeon captured from a lower mid-Columbia River reservoir for population assessment. (*Photo courtesy of Ray Beamesderfer*).

1.2 Background

The Columbia Basin historically supported a very large and productive population of white sturgeon that may have ranged from the ocean upstream in the Columbia, Snake, and Kootenai rivers for hundreds of miles (Figure 1). 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, and genetic work has shown historical ancestry among major Pacific coast rivers in the Pacific Northwest, California, and British Columbia (Anders and Powell 2002; Drauch Schreier et al. 2013).

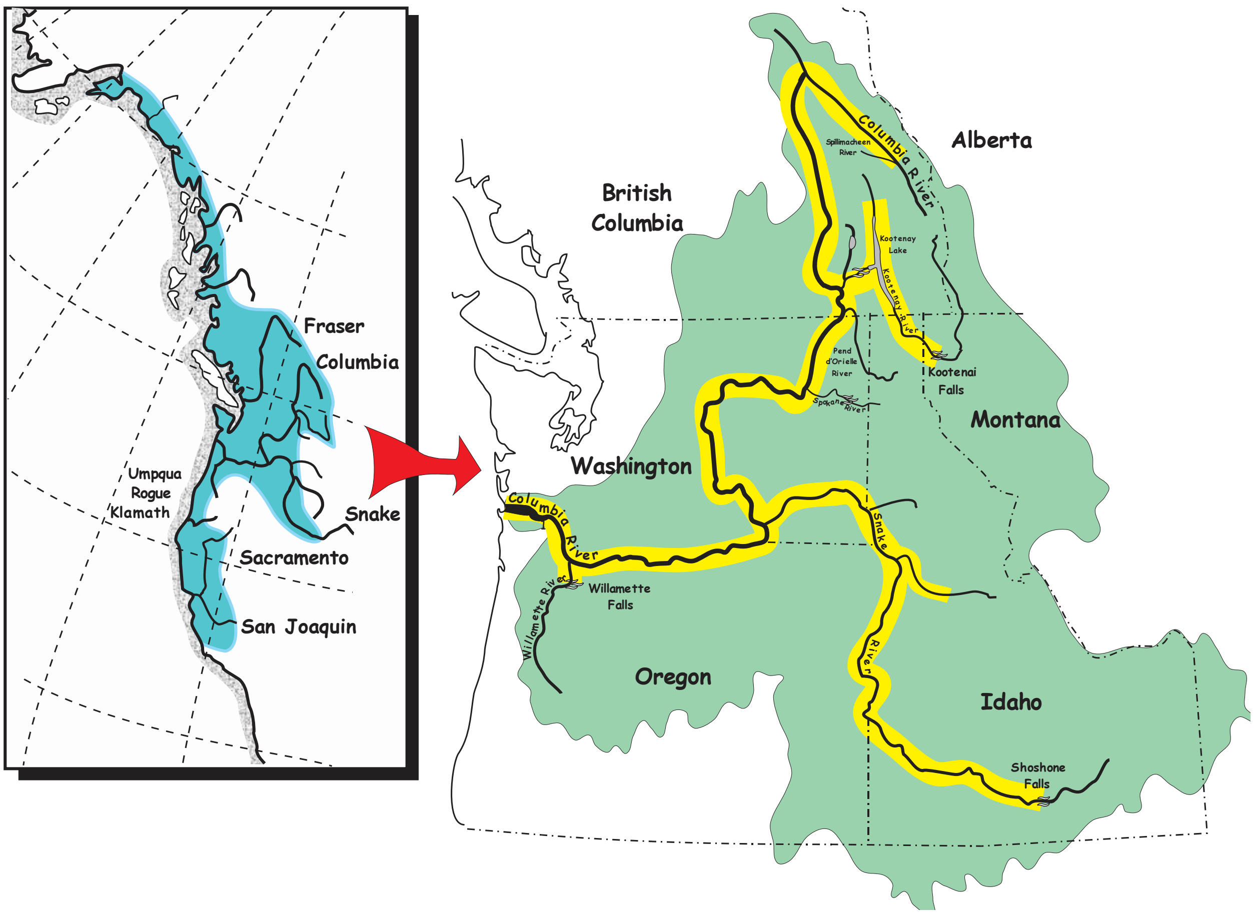


Figure 1. Historical range of white sturgeon.

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. Historically, habitats occupied by white sturgeon were extremely dynamic, with large seasonal and annual variation. Distribution and abundance of prey and predator species also varied widely in response to spatial and temporal patterns. Anadromous fishes, including salmon, eulachon, and lamprey historically provided tremendous seasonally abundant food resources.

Sturgeon evolved life histories ideally suited to these large, diverse, and dynamic systems (Gross et al. 2002). 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 or occupy feeding positions in such conditions. 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 web 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 river systems. 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 and historically available 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, and has led to predominantly downstream movement of individuals and gene flow (Jager et al. 2001).

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 once may have been a single population or a series of broadly overlapping metapopulations, has now been fragmented by dam construction into a series of largely isolated subpopulations. The unimpounded lower Columbia downstream from Bonneville Dam continues to support a significant subpopulation, but population productivity has likely been considerably impaired by restricted access to thousands of miles of upstream spawning and juvenile rearing habitat. Upstream from Bonneville Dam, status varies among impounded subpopulations from marginally productive to functionally extirpated. Subpopulations in most impoundments consist mainly 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 in these populations 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 (Gross et al. 2002). 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 with limited fisheries. Unfortunately, habitat conditions in all impounded areas are no longer suitable for supporting sturgeon production adequate to provide cultural and subsistence fisheries, a significant harvestable surplus, or in many cases to even support sustainable populations.

White sturgeon in the Columbia Basin have long been a focus of fishery monitoring and management activities (Figure 2) with the first significant sturgeon research beginning in the 1940s when Bajkov (1949, 1951) initially described the biology of the species. 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 (Figure 2).

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 Columbia River Basin and formal listing of the Kootenai and upper Columbia populations under U.S. ESA and Canadian SARA legislation respectively.

Collectively, these efforts have now:

- provided a fundamental understanding of the biology, population dynamics and habitat requirements, which vary among subpopulations within the basin,
- determined the status of subpopulations throughout the basin,
- identified key life stages and potential limiting factors,
- provided a firm scientific basis for fishery management consistent with current status of many subpopulations, and
- begun to explore the feasibility and effectiveness of protection, mitigation, and restoration alternatives.

White sturgeon management in the Columba Basin is currently at a critical juncture. We have largely completed basic inventory and assessment work in most areas. We are now at the point of making hard decisions regarding goals, strategies, investments and schedules for future sturgeon management and conservation efforts. However, challenges exist given the variable nature of limitation among subpopulations and because management, conservation, and restoration efforts exist at different stages of development across the Basin. Nonetheless, management decisions made now and in the near future regarding the direction of future sturgeon projects will determine white sturgeon status for decades to come. This document was developed to provide an initial broad-scale planning framework to help design and coordinate the next generation of sturgeon work throughout the region. In a long lived, late maturing species like white sturgeon, the presence of adequate number of juveniles is critical to restoration and recovery efforts across the Basin.

1.3 Purpose of Framework

This framework document describes at a broad-scale where we came from, what we know, and where we are going with respect to white sturgeon. This framework will help to provide an overarching framework to help guide and coordinate future conservation, restoration, mitigation, and management efforts for white sturgeon 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 activity, responsibility, or authority by any party. The sturgeon framework represents the collective effort, expertise, and current vision of a working coalition of parties with intersecting needs and interest. The Framework represents a current snap shot in time and is intended to inform current and future sturgeon-related planning and regulatory processes undertaken by parties throughout the basin.

1.4 Framework Organization

This framework:

1. Summarizes the available information on sturgeon biology, status, fisheries, and limitations across the basin;
2. Describes a comprehensive basin-wide 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 different areas within the Columbia Basin in the context of the comprehensive objectives and strategies, and
5. Includes a series of overarching conclusions and recommendations based on the basin-wide assessment.

Framework 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).

1.5 FRAMEWORK AREA & MANAGEMENT UNITS

This Framework encompasses the range of white sturgeon within the Columbia River Basin. Conservation, mitigation, and management of Columbia River white sturgeon is complicated by their widespread distribution, fragmented population structure, and differences in status throughout the basin. 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. In turn, 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. The hierarchical organization of this document is designed to 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. However, conclusions about limiting factors, research and restoration needs and future work plans should be made with all dedicated sturgeon planning areas in mind. Finally, the guidance for subsequent implementation of work plans, schedules, and agreements in these areas must be incorporated into the basin-wide plan.

This Framework recognizes nine sturgeon management units encompassing the historical distribution of white sturgeon in the Columbia and Snake river basins in Oregon, Washington, Idaho, Montana, and British Columbia (Figure 4). Management units (MUs) were defined during a facilitated workshop held in connection with the development of this framework (Beamesderfer et al. 2011). Workshop participants initially delineated these MUs 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. Genetic Management Units (GMUs) were also developed that represent river reaches containing sturgeon with similar genetic characteristics (Drauch Schreier et al. 2013); GMUs are designed to assist in the implementation and guidance of sturgeon conservation and management measures (Welsh et al. 2010)

The nine MUs 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 Kootenay/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 4).

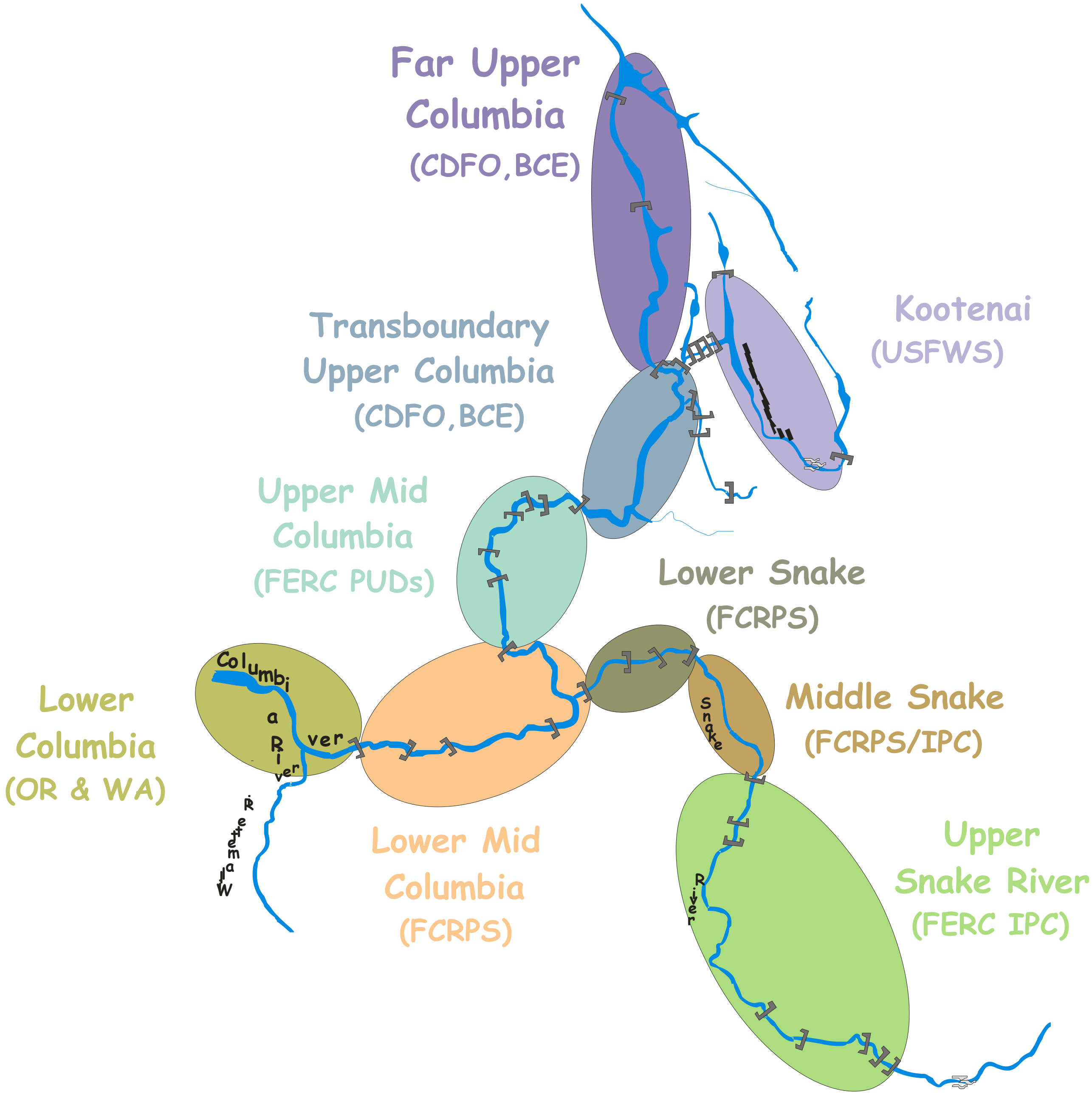


Figure 4. Nine management units (MUs) addressed by the Framework. Primary management entities are identified for each (OR = Oregon, WA = Washington, FCRPS = Federal Columbia River Power System, FERC = Federal Energy Regulatory Commission, PUD = Public Utility District, IPC = Idaho Power Company, USFWS = U. S. Fish and Wildlife Service, CDFO=Canadian department of Fisheries and Oceans, BCE= British Columbia Ministry of Environment).

1.6 A Brief History of Sturgeon Planning

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

In 1983, concern for trends and the general lack of information about sturgeon 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 workshop 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 these 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. The 1992 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 their historic range, sustaining optimum benefits for diverse consumptive and non-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 to develop 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 basin-wide management plan, data gaps at a basin 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.

1.7 Planning & Policy Guidance

The Framework reflects guidance from a complex of plans, policies, and programs governing the activities of entities with related responsibilities and authorities. Future plans, programs, actions, and priorities will benefit from guidance provided in this sturgeon Framework.

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, and the Kootenai River 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 (NCPP 2009), 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 and in various subbasin plans.

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 several 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 isolation effects 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 throughout the mainstem, largely by protecting, enhancing, and restoring habitat quality and connectivity, especially critical 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. The Mainstem Plan also recommends that 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 5). Since the Kootenai River white sturgeon population was listed as Endangered in 1994 and restoration actions were initiated in 1988, Kootenai River 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.

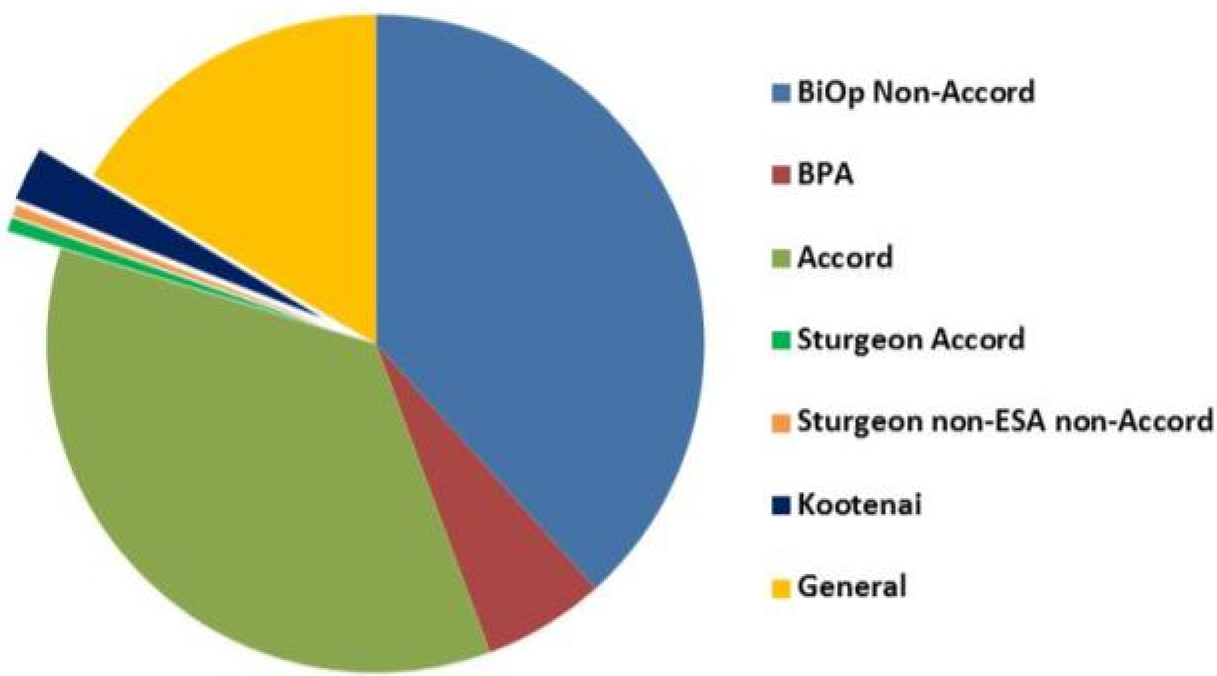


Figure 5. Sturgeon share of current spending under the Northwest Power and Conservation Council Fish and Wildlife Program.

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). Cost figures are presented in thousands of dollars.

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 Native Fish Conservation and Aquaculture Program	ESA	3,101	3,178	2,677	2,677
1988-065-00	Kootenai River Fishery Investigations	ESA				
1995-027-00	Lake Roosevelt Sturgeon Recovery	General	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	General	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***

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: 1) is a vulnerable aggregation susceptible to significant population declines within a specific area; and 2) contains populations of recreational or commercial importance, and 3) is 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 of 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 three farthest downstream Columbia River impoundments upstream from 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 current and optimum population levels, life history characteristics, recruitment levels, 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 its management authority, which is shared with Indian tribes. WDFW partners with other federal and tribal agencies and Public Utility Districts in implementing white sturgeon restoration programs in this portion of the Columbia River and has collaborated with other state and tribal agencies in limited monitoring of white sturgeon populations in Snake River impoundments downstream of Lower Granite Dam.

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 currently engaged in a State Conservation planning effort for impounded sturgeon populations from Bonneville Dam upstream 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 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, Fisheries and Oceans Canada, Montana Fish Wildlife & Parks, U. S.

Army Corps of Engineers, and the Bonneville Power Administration. Due its federal listing status in the US, conservation, management, and recovery actions are guided by the federal recovery plan. During recent years, the KTOI, in conjunction with other regional entities, has developed five-year operational plans to coordinate these activities (Anders et. al 2005).

Montana

White sturgeon occur in 21.7 miles of the Kootenai River in Montana 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.

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 (also known as Lakes Indians), whose former homeland was along the Arrow Lakes, are now distributed among other tribal groups in the West Kootenay area and 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 Kootenai Tribe has been successfully incubating, hatching, raising and releasing hatchery-reared sturgeon since 1990 (Beamesderfer et al. 2013). Subsequent monitoring shows the juveniles are surviving, and the oldest individuals are nearing sexual maturity. The Kootenai Tribe of Idaho is also implementing the large-scale ecosystem-based Kootenai River Habitat Restoration Program in a 55-mile reach of the Kootenai River in Idaho. Additionally, the Tribe working in coordination with Idaho Department of Fish and Game and Ministry of Forests, Lands and Natural Resource Operations is implementing a nutrient addition program in the Kootenai River and Kootenay Lake.

The Spokane Tribe of Indians and Colville Confederated Tribes have taken an active role in the Lake Roosevelt Sturgeon Recovery Project (LRSRP), a multi-agency project that is responsible for assessing the white sturgeon population in Lake Roosevelt and working toward restoration of natural recruitment to levels that can support beneficial uses (harvest). In addition, the Colville Tribes began implementation of the White Sturgeon Enhancement Project in 2012 that will complement the assessment and recovery efforts initiated by the LRSRP. Both projects receive 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) and the Okanagan Nation Alliance, who are partners in the Upper Columbia White Sturgeon Recovery Initiative.

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, and 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 dams. 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 an annual review of sturgeon management regulations. The effect of size limits, sanctuaries and other regulations on the harvest guidelines are 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, and spawning potential and appropriate sturgeon fishing sanctuaries is essential to successfully managing these populations.

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, which includes the Ktunaxa and Shuswap Nation governments and the Okanagan Nation Alliance are assisting in the development of appropriate 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 in the upper Columbia River in Canada were closed and Canadian First Nations people voluntarily stopped their sustenance harvests. This important step allowed more fish to survive 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. The 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 research in the 1990s found that young white sturgeon were becoming alarmingly rare in the Upper Columbia. 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 (Hildebrand and Parsley 2013).

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 in 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 required by a listed status. 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. However, implemented or planned salmon restoration 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 protected 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 and Washington, 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.

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 operating 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 (2038). To meet this goal, Grant County PUD has implemented 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 by 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 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 and 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.

Figure 3. Photo of a juvenile white sturgeon (*Photo courtesy of the Freshwater Fishery Society of British Columbia)*.

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 weight 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 a lack of 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 an extendable tube-like mouth and four barbels located on the ventral surface of a hard protruding snout (Figure 6). 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 may be an adaptation to fast moving water.

Figure 6. Eversible proboscis of a white sturgeon. (*Photo courtesy of*).

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) and 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 (NMFS 2005). 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 pelvic fins in green sturgeon (vs. posterior to the posterior insertion of the pelvic fins in white sturgeon) (Figure 7).

Figure 7. 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 inhabit large rivers, estuaries, and near-shore ocean habitats from Ensenada, Mexico to the Aleutian Islands in Alaska (Figure 1). This species spawns exclusively 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 basins (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).

Life History

White sturgeon can be characterized as "periodic reproductive strategists" (Winemiller and Dailey 2002). Periodic strategist species are typically long-lived 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 or intermittent 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.

Beyond the larval stage, 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) in the Lower Columbia River. The sub-adult stage begins when white sturgeon can enter estuarine and marine environments and ends at sexual maturity (Figure 8). The term sub-adult can also be used to describe older juveniles in blocked areas nearing initial sexual maturity in populations with no access to the estuary given their ecological and behavioral similarity to adults.

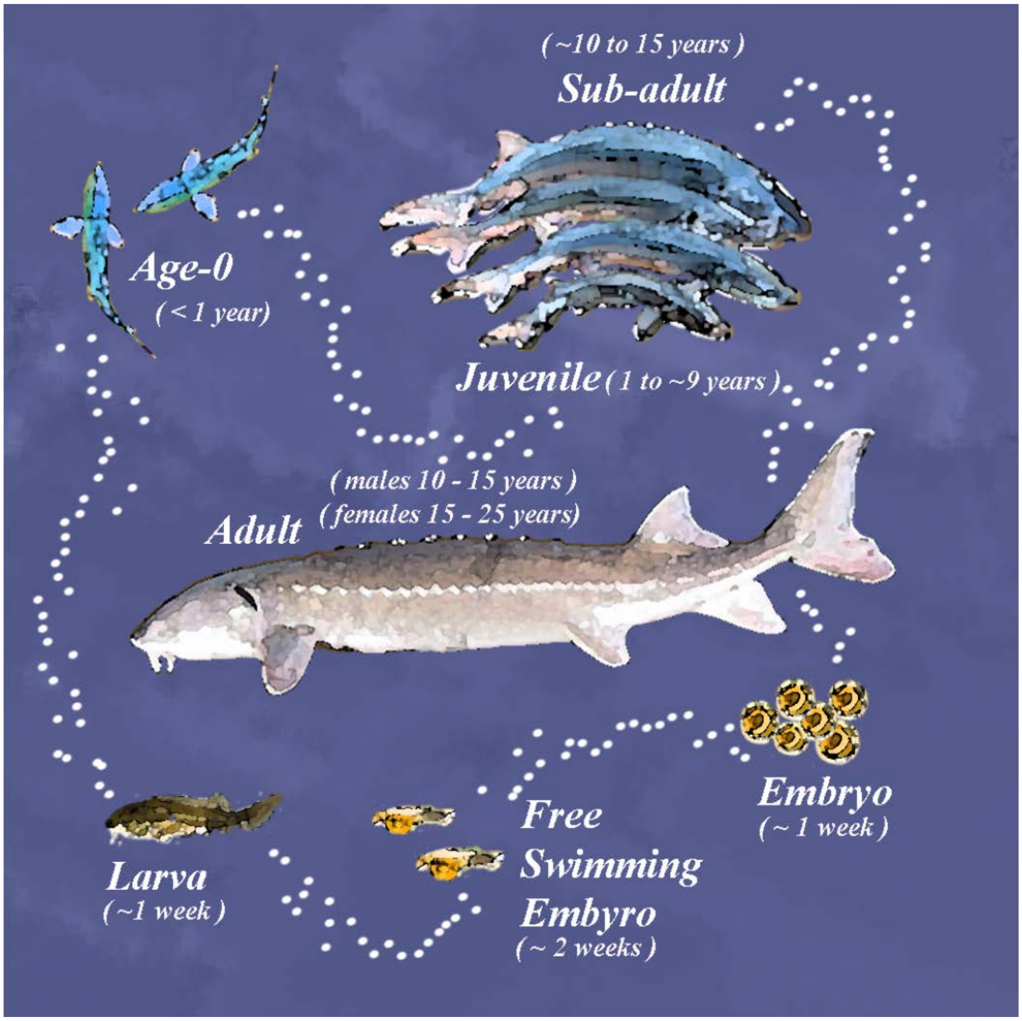


Figure 8. White sturgeon life cycle including embryo, free-swimming embryo, larva, age-0, juvenile, sub-adult and adult life stages.

Spawning

Behavior

White sturgeon are broadcast spawners, releasing their eggs and sperm into the water column over boulder and cobble substrates (Hanson et al. 1992; Parsley et al. 1993). Fish gather in aggregations to spawn and several males typically spawn with each female. Observed spawning has been 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 and specific locations of sturgeon spawning migrations prior to development of the hydropower system is uncertain. Based on recent nuclear (Drauch Schreier et al. 2013) and older mitochondrial DNA evidence (Anders and Powell 2002) indicating expansive gene flow over large areas of the Columbia River basin, it t appears likely that fish using marine waters, the estuary, and the lower river may have migrated considerable distances upstream to find suitable spawning habitats.

Timing

Spawning in the Columbia River typically occurs during late spring to early summer when water temperatures reach 12 to 14°C (Hanson et al. 1992; Parsley et al. 1993; Parsley and Beckman 1994; Golder 2011c; Howell and McLellan 2007a, 2008, 2011; McAdam 2013; Anders et al. 2002)(Figure 9). 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 and a shortened annual period of suitable water temperature. However, sturgeon in the Arrow Lakes Reservoir and the 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.

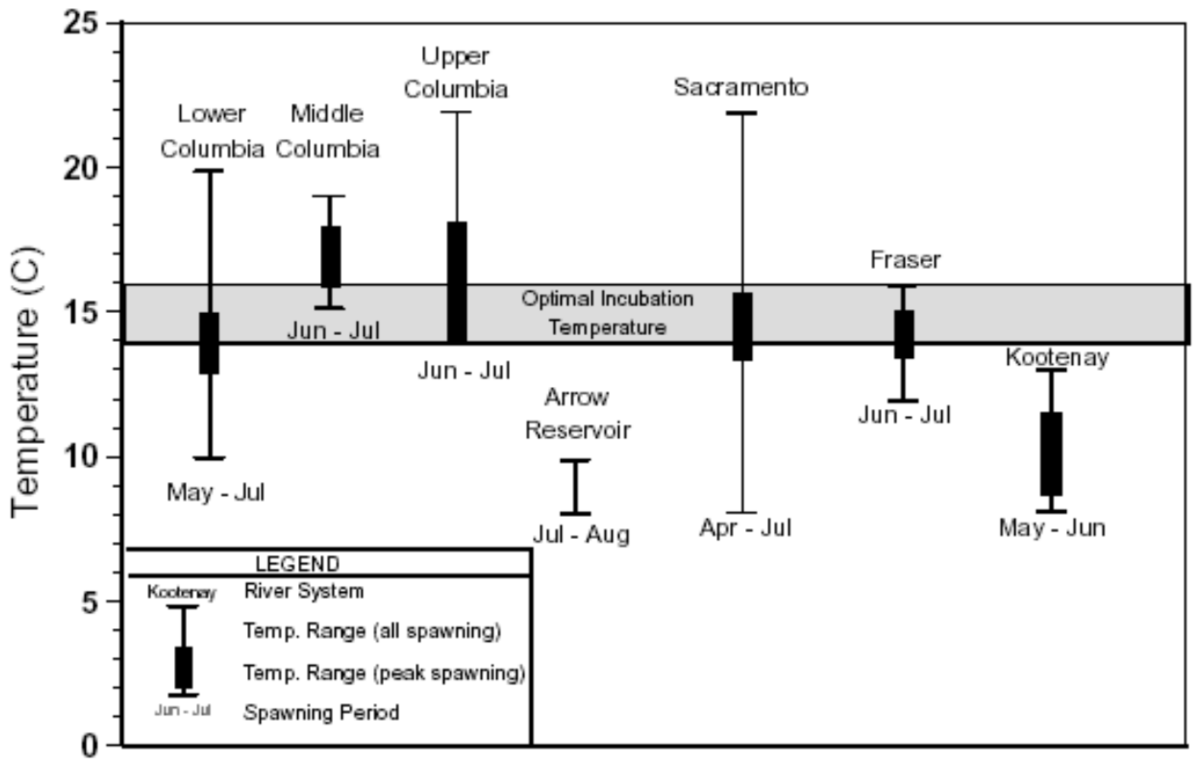


Figure 9. Water temperatures associated with spawning by white sturgeon (Anders and Beckman 1993; Parsley et al. 1993; Hildebrand and McKenzie 1994; RL&L 1995, 1996a, 1996b, 1996c, 1997a, 1998a, 1998b, 1998c, 1998d, 1999a, 1999b, 1999c, 1999d; Perrin et al. 1999, 2000).

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, 2001). Similar problems were not apparent at colder temperatures. Cold-water requirements for successful completion of ovarian development (vitellogenesis) have also been documented for other sturgeon species (Kazanskii 1963; Kazanskii and Molodtsov 1973; Williot et al. 1991; Chebanov and Savelyeva 1999).

Habitat Requirements

Sturgeon in spawning condition migrate to spawning reaches and select spawning sites appear to be based on a selected combination of substrate composition, water velocity, turbulence and depth. 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; however, the specific combinations of factors that determine site selection and subsequent spawning success are poorly understood. Although conditions at spawning sites have been documented, alternative sites appear to provide similar conditions but are not utilized. It appears that sites are chosen based on interacting combinations of conditions rather than any specific parameter by itself. Spawning site suitability and its availability may have been significantly reduced by river impoundment, which has inundated many sections of riverine habitat.

<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 systems (Figure 10), 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; Kock et al. 2006). 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, or depositional areas.

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 (Figure 10).

<u>Velocity</u>. 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)(Figure 10). 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. Many sturgeon researchers have subsequently emphasized the need to account for near-bottom velocity as opposed to a mean column velocity (< 1 m from the substrate) as relevant to sturgeon spawning and incubation concerns (B. Kynard, B.K. Riverfish, Amherst MA., personal communication 2013) Based on an analysis of egg distributions on egg mats from 2000 to 2005, results of a 3D numerical model of the Waneta spawning area indicated that over 95% of the eggs were collected from areas with near-bottom flow velocities >1.0 m/s over the entire egg incubation period (ASL et al. 2007).

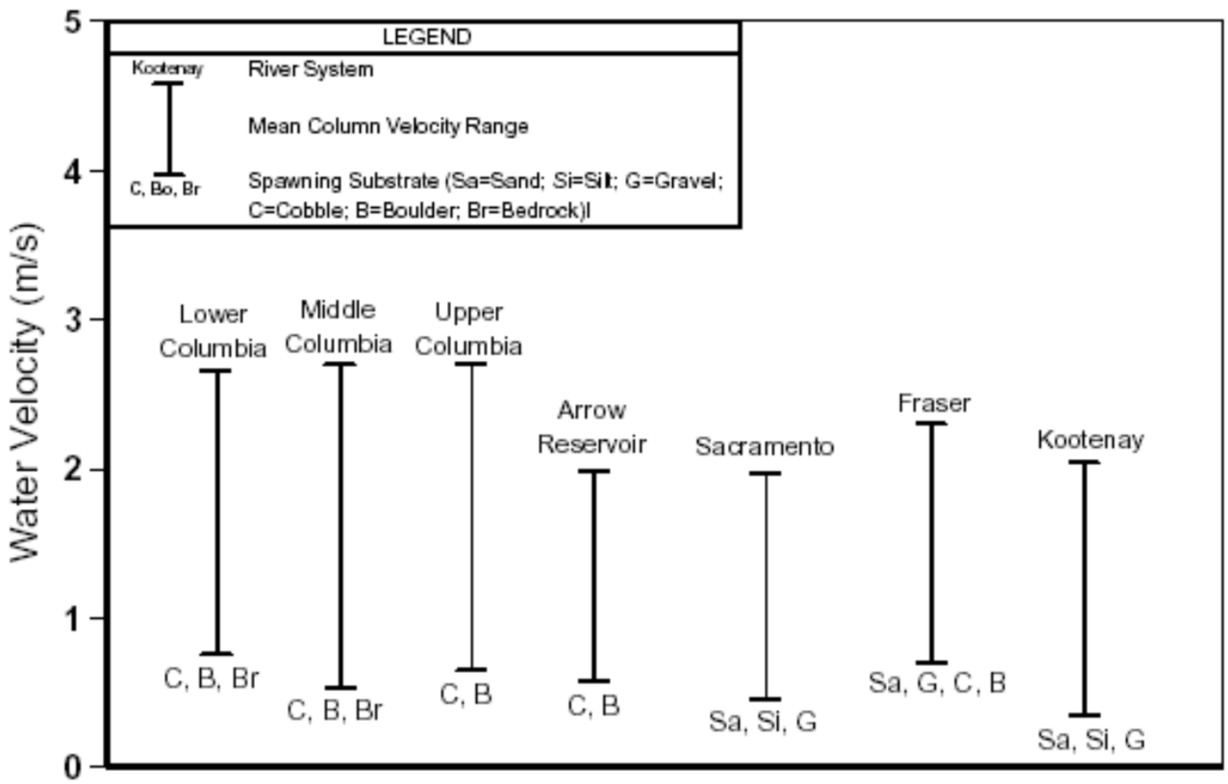


Figure 10. Substrates and water velocities associated with sturgeon spawning site selection (Parsley et al. 1993; RL&L 1996a, 1996b, 1996c; Perrin et al. 2000).

Parsley and Beckman (1994) observed temporal correlations between higher catch of sub-yearling white sturgeon in the three lower Columbia River reservoirs and high-discharge years that provided higher velocities. However, it should be noted that these results are correlative, and while higher discharge may provide more spawning habitat, based on the spatial extent of recommended velocities, it may also result in hydraulic conditions that promote increased survival of early life stages. Lower velocities (0.2-1.0 m/s) have been reported from areas within the spawning reach for Kootenai white sturgeon during the spawning season (Paragamian et al. 2001). However, spawning in that system does not lead to recruitment because eggs are deposited in depositional areas that appear generally unsuitable for egg survival (Anders et al. 1993; 2002; Kock et al. 2006).

Turbulence. Turbulence is a feature common to all documented white sturgeon 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 creating larger areas of turbulence. Turbulence is relatively easy to distinguish but difficult to measure. Consequently, its association with 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 together produces cascades, eddies, or confluences (Figure 11).

Figure 11. White sturgeon spawning site in Waneta eddy at the mouth of the Pend d'Oreille River on the transboundary reach of the upper Columbia River. Arrow indicates where spawning occurs. The black dotted line is the approximate separation between the Pend d'Oreille and Columbia flows, the white dotted line shows the approximate egg deposition area, and the circles represent the egg capture locations with the size of the circle proportional to egg catch rates. Photo was taken in late summer at low Pend d'Oreille flows and doesn't show the high velocity. (*Photo courtesy of L. Hildebrand, Golder Associates, Castlegar BC, Canada*).

Turbidity. Although white sturgeon spawning in unaltered rivers is associated with high turbidity, it is unclear whether the success of spawning or recruitment directly depends on turbidity or if this condition is simply correlated with others associated with successful 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).

Depth. 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 and like other behaviors may differ among populations through the species range. 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.

Incubation & Early Life History

Early life stages include embryo, free swimming embryo, and larva (Balon 1984, Parsley et al. 2002, van der Leeuw et al. (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 occurs immediately after hatch in some populations when free-swimming embryos leave the substrate and drift in the water column (Brannon et al. 1987; Conte et al.

1988). However, considerable variation among sturgeon species and populations has been reported regarding free embryo behaviors and survival strategies, which are thought coevolved with habitat availability and food resource availability (B. Kynard, BK Riverfish, Amherst MA.) personal communication March 2013). Some laboratory and field studies suggest that at least a portion of white sturgeon free embryos (yolk-sac) enter the water column and undergo a short, "weak" dispersal from the spawning area within a few days (0-5) of hatching (Brannon et al. 1985; Kynard and Parker 2005; Kynard et al. 2010; Howell and McLellan 2011). During their dispersal, the free embryos exit the substrate and drift with the current near the river bottom, as evidenced by captures in benthic "D-ring" style plankton nets (Parsley et al. 1993; Howell and McLellan 2011). Other studies indicate that the innate behavior of free embryo white sturgeon may be to initiate hiding immediately upon hatch. Immediate hiding behavior may be population specific, as Kootenai River white sturgeon free embryos did not disperse in a laboratory study (Kynard et al. 2010), or may be related to the quality of hiding habitat (substrate) in the spawning area (McAdam et al. 2011) or the time of day or night (Kynard et al. 2010).

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). Dispersal of sub-yearling white sturgeon (free-embryos, larvae, and juvenile developmental stages) can occur over substantial distances. Sub-yearling white sturgeon were distributed over 200 km downstream from the known spawning area below Bonneville Dam in the lower Columbia River (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).

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).

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). After the short initial dispersal, if it is exhibited at all, white sturgeon free embryos enter a hiding phase that lasts for approximately 7 to 15 d, depending on water temperature. During the hiding phase, the free embryos settle onto the bottom, presumably within the interstitial spaces of the substrate, where they remain until the majority of their yolk reserves have been consumed and they reach the approximate developmental stage of early larvae (Brannon et al. 1985).

While variation in early life behaviors occurs among populations, white sturgeon free embryos must eventually emerge from hiding to begin the transition to exogenous feeding. Columbia and Kootenai River white sturgeon early larvae initiate a strong dispersal upon emergence from hiding, which occurs near the bottom (Brannon et al. 1985; Kynard et al. 2010; Howell and McLellan 2011); whereas, Sacramento River white sturgeon did not disperse until they had reached the juvenile developmental stage (Kynard and Parker 2005).

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 seasonally and generally within and among rivers (P. Anders, Cramer Fish Sciences, personal communication).

White sturgeon eggs, embryos, free embryos, 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 free embryo larval concealment areas (Anders et al. 2002; Parsley et al. 2002; Kock et al. 2006). Free embryos and 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 free embryo or larvae dispersal phase might also transport these early life stages into downstream reservoirs where food may be scarce, introduced predators may be abundant, or the post-impoundment scenario may force spatial or temporal asynchrony between available and required habitat conditions. 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 in some basin populations.

Food & Feeding

White sturgeon are primarily benthic feeders on invertebrates and fish, and 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 and the food web. 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 surprisingly selective feeders. 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) 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 collected from 41 juvenile Kootenai River white sturgeon in Idaho and BC during 2002 most commonly included Chironomid larvae, which 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 and ability to consume increasingly larger prey as they mature. 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. Lower Columbia River white sturgeon feed 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, and mayfly and stonefly larvae. Non-native mysid shrimp entrained from Arrow Lakes are an important food item among sturgeon in the upper portions of the Transboundary reach downstream from H. L. Keenleyside Dam (Golder 2009a). Lepla and Chandler (1998) found that sturgeon diets in the Bliss reach of the upper Snake commonly included chironomids, caddisfly larvae, snails, clams, and shrimp.

Movements & Habitat Use

During early life stages, white sturgeon in the lower Columbia River use a variety of habitats. Age-0 fish 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 captured 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). Some 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 some 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. 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 and range widely, presumably in search of scattered or mobile food resources. Many white sturgeon movement and migration patterns appear to be associated with 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 deep 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.

2.3 Life History Parameters

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.

Fish up to about 10.5 feet total length and 400 pounds have been measured in recent stock assessment sampling in the Columbia Basin (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. Considerable differences in condition factor have been documented between lower and upper basin populations (Figure 12). 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 fish of similar length from the Kootenai River. Lower condition factors in the upper basin are typically attributed to lower productivity and food availability.

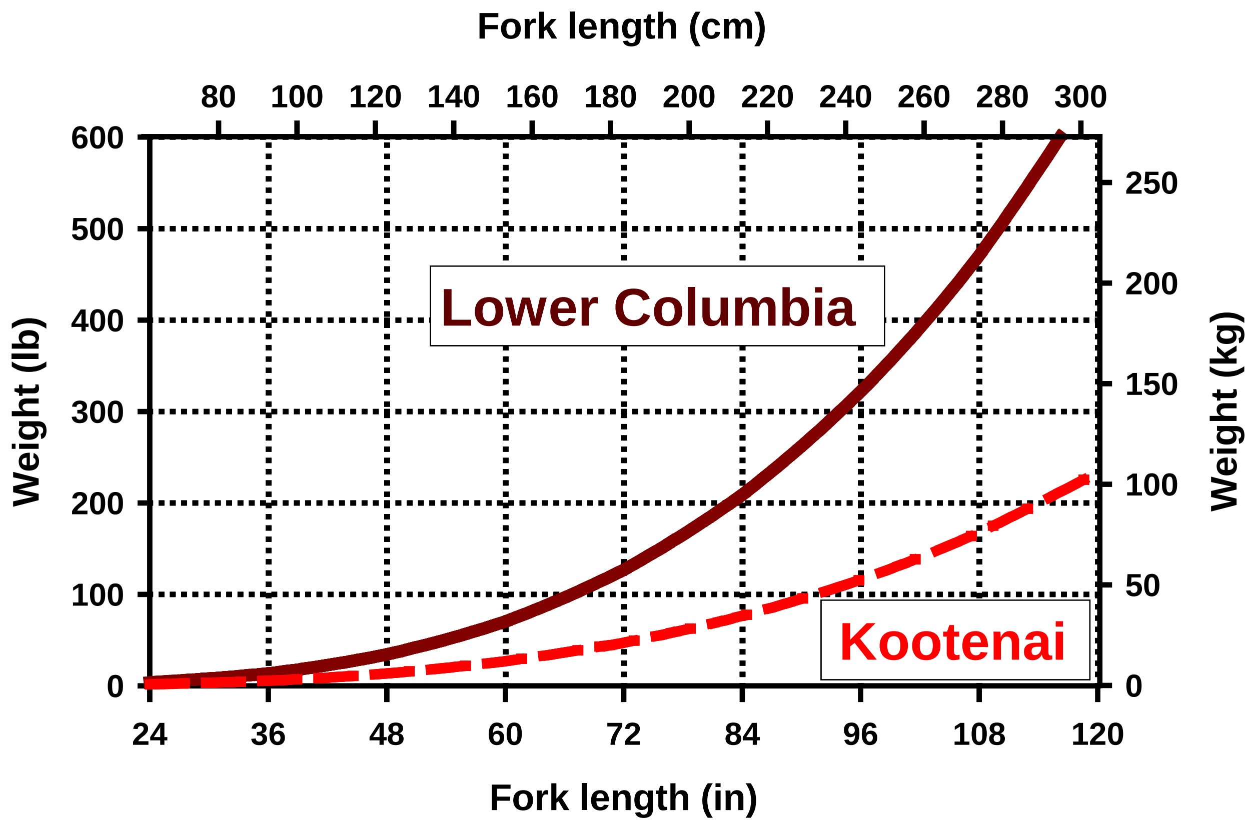


Figure 12. Average length-weight relationship for white sturgeon based on lower Columbia River (DeVore et al. 1995) and Kootenai samples (Paragamian et al. 2005).

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

Location	Maximums			Length-weight[a]		Condition	Age-length relationship[c]			Reference
	Size (FL cm)	Weight (kg)	Age (yr)	α	β	Wr[b] (%)	L_{inf} (FL cm)	k	t0	
Lower Columbia										
Estuary – Bon. Dam	263	188	65	2.85E-06	3.23	112	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
McNary Pool & H.R.	272		50	2.47E-06	3.23	97				Rien & Beiningen 1997
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										
Ice Harbor Pool	243	108	47	6.85E-06	3.02	92	488	0.012	-3.4	DeVore et al. 1998
L. Monumental Pool	221	89	34	7.61E-06	3.01	99	596	0.010	-5.7	DeVore et al. 1999
Little Goose Pool	240	125	58	1.31E-05	2.91	97	278	0.034	-1.2	DeVore et al. 1999
Lower Granite Pool	236		29	3.30E-06	3.12	103				Lepla 1994
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 = α Length $^{\beta}$

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

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

[d] Parameters based on total length.

Age & Growth

Large 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.

Growth of individual white sturgeon is highly variable, evident even during the first few months of life (Figure 13). 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.

Figure 13. Juvenile white sturgeon at approximately 2-3 months of age. (*Photo courtesy of Ray Beamesderfer*)

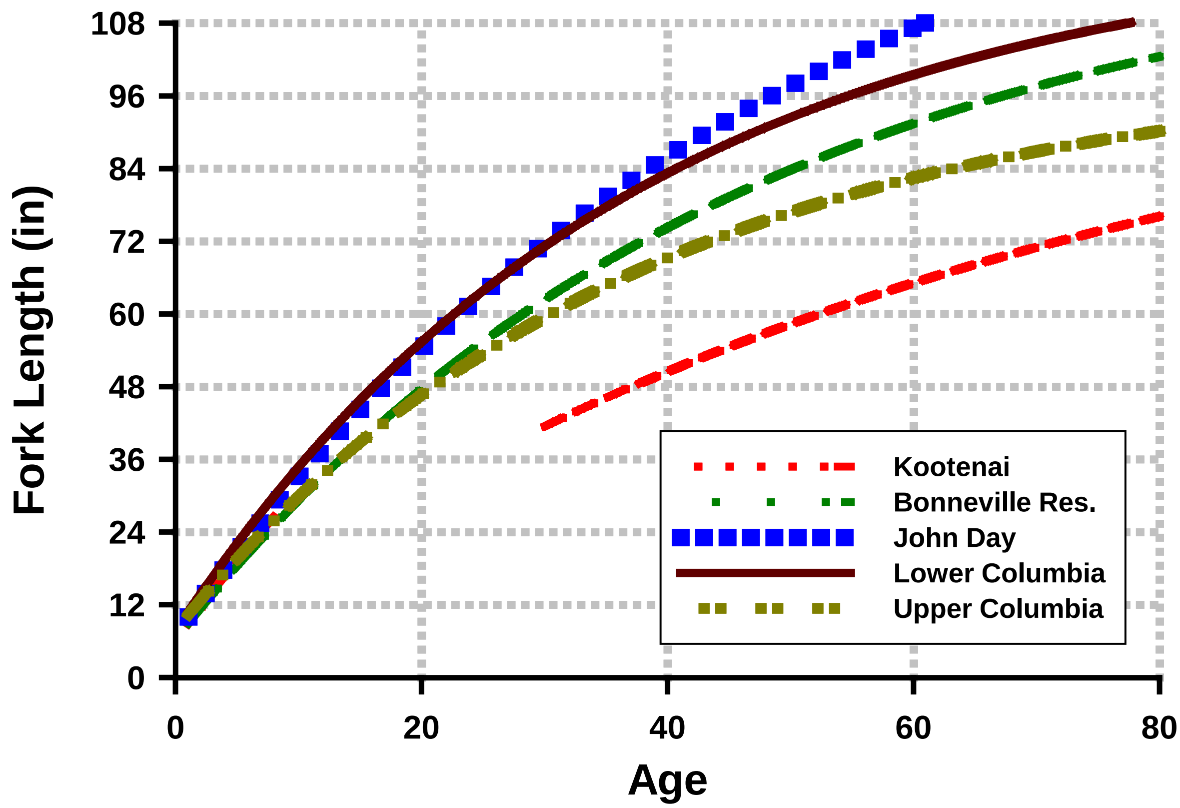


Figure 14. White sturgeon von Bertalanffy growth curves (parameters from Table 3).

Individuals from inland white 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 found in lower river and estuary habitats

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.

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 at initial maturation size and in subsequent spawning periodicity. Reported median sizes of initial maturation in females ranged 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 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; 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).

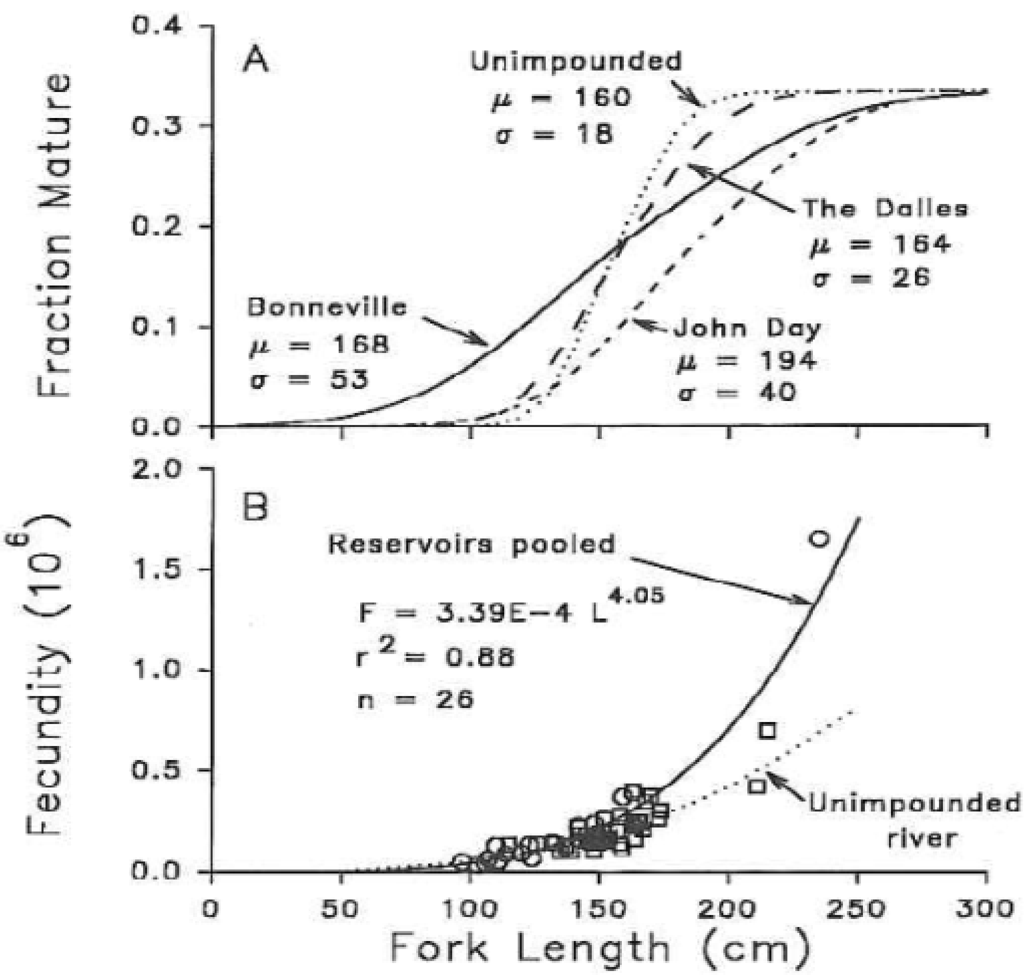


Figure 15. (A) Maturity and (B) fecundity (millions of eggs) versus size of female white sturgeon in three reservoirs and the unimpounded lower Columbia River (from Beamesderfer et al. 1995).

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 in captivity, males are capable of spawning annually and females every two years (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.

Recruitment

Recruitment typically 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 could be sustained by frequent year class production or 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. Recent recruitment analysis of Kootenai River white sturgeon revealed ongoing recruitment limitation or failure based on catches of typically less than 10 individuals produced annually during 43 of 50 recent years from sampling between 1977 and 2011 (Rust and Wakkinen 2011). 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 for most basin sturgeon sub-populations, 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 and embryos; 3) decreased predation on free embryos, larvae and juveniles; 4) dispersal to productive mainstem rearing areas; 5) increased flooding of side channel and slough areas that provide higher quality rearing habitats than mainstem areas; 6) effects of related conditions such as temperature, or 7) some combination of these factors.

Survival/Mortality

The longevity of white 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 such small differences this small. Survival of hatchery released juveniles in the upper Columbia River increased substantially after the first 6 months in the river for all cohorts. The survival was estimated to be approximately 28% for the first 6 months in the river and was approximately 85% for age 1 to age 6 fish. (Irvine et al. 2007; Golder 2009a). Post-stocking survival rates of Kootenai River white sturgeon varied by release time and location and by fish size at release (Beamesderfer et al. 2013); past post-stocking survival initially averaged around 60% during the first year-at large and approximately 90% during all subsequent years for fish released at generally one year of age (Ireland et al. 2002b).

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

2.4 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 (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).* Octoploidy 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).

However, Drauch Schreier et al. (2013) published long-awaited microsatellite-based population structure for the entire range of white sturgeon. This study, based on analysis of over 2,000 samples, provided key findings about white sturgeon population genetic structure that is very helpful to management of the species throughout its range, including the Columbia Basin. Authors reported that an isolation by distance pattern was exhibited for by white sturgeon across the Columbia Basin, which was supported by among-drainage population structure analysis results. Results provided little genetically-based support for managing sturgeon in each river reach (between dams) in the Columbia-Snake drainage as separate populations as adjacent reaches showed little to no genetic divergence. Thus, results of this comprehensive analysis support the use of five genetic management units further described in the following sections of this document (Figure 19). These five genetic managements have somewhat flexible geographic boundaries but contain groups of fish that are more genetically similar to each other than to fish in adjacent units, with genetic divergence increasing with increasing geographic distance.

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 and historical and finer-scaled current patterns of relatedness within and among populations.

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 latitudinal 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 was 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).

Recent information from Drauch Schreier et al. (2013) provides analysis of fine-scale population structure. They incorporated an exhaustive collection of white sturgeon from throughout their range and data from thirteen polysomic microsatellite loci to further examine white sturgeon population structure. The results confirmed that population structure varies regionally and within major river basins (Figure 16) (Hildebrand and Parsley 2013; Drauch Schreier et al. (in prep)). Interestingly, similar large-scale population structuring, useful for developing genetically-supported management units (Welsh et al. 2010), was reported for mtDNA (Anders and Powell 2002) and nuclear (microsatellite) studies (Drauch Schreier et al. 2013), may provide considerable management flexibility regarding founder and recipient stocks within Columbia Basin MUs for white sturgeon.

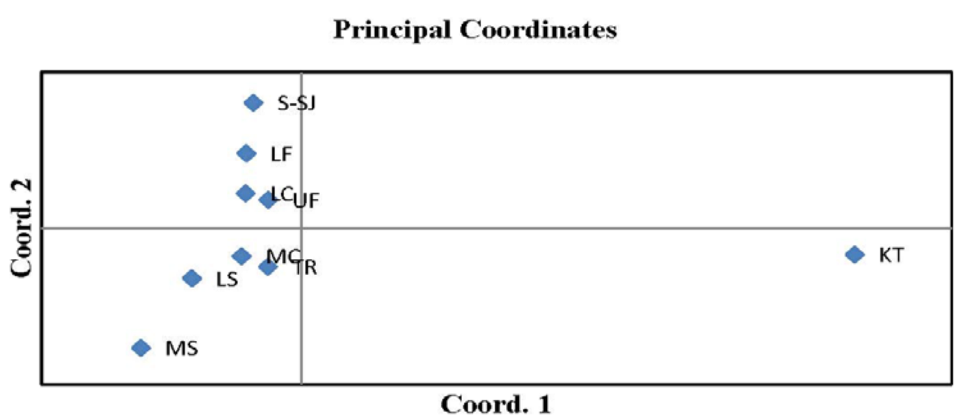


Figure 16. Principle coordinates analysis illustrating genetic relationships among White Sturgeon inhabiting different regions throughout their range. S-SJ = Sacramento-San Joaquin, LC = Lower Columbia, MC = Middle Columbia, TR = Transboundary Reach, KT = Kootenai, LS= Lower Snake, MS=

Middle Snake, LF= Lower Fraser, and UF= Upper Fraser. An arrow depicting the Transboundary Reach (TR) was added for emphasis. Reproduced with permission from Drauch Schreier et al. (in prep).

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 mtDNA haplotypes were negatively correlated with inland distance from the Pacific Ocean in all river systems studied (Anders and Powell 2002). All haplotypes 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). At a larger spatial scale, Drauch Schreier et al. (2011d) observed little genetic difference between the middle Columbia, transboundary reach, and lower Snake River white sturgeon.

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. Levels of genetic diversity 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; Drauch Schreier et al. 2011d). 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 nine 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 17). 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 alleles, 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 the Kootenai River population (Figure 18).

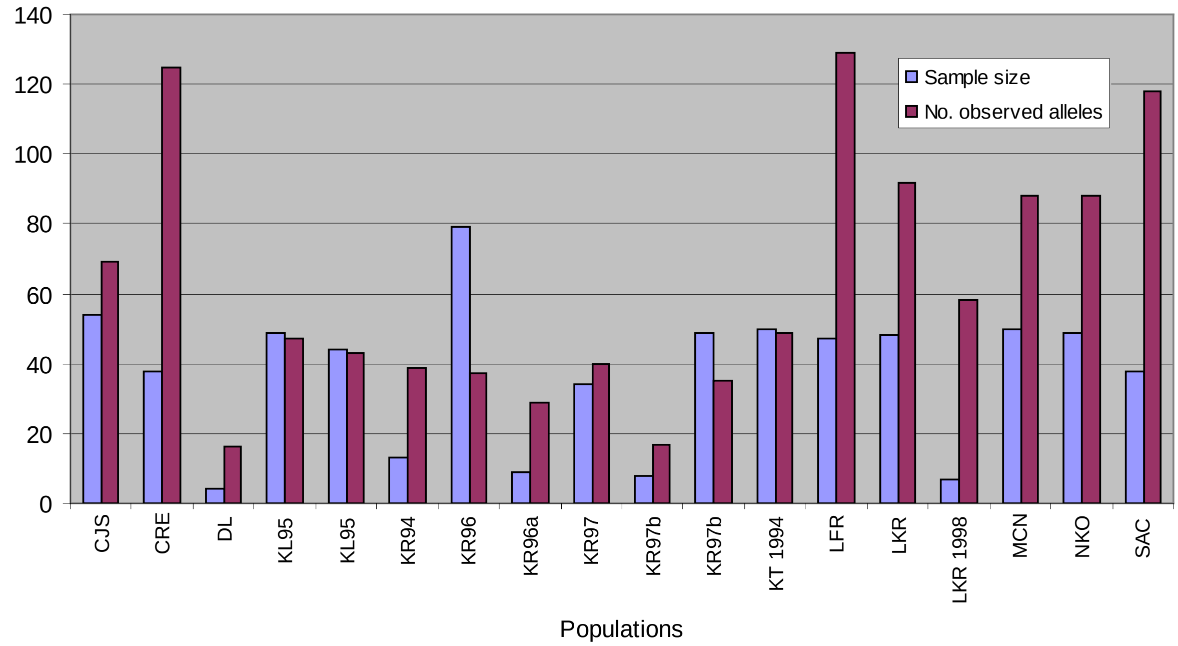


Figure 17. Sample size and number of observed alleles from 18 population or sample groups of white sturgeon (From Rodzen et al. 2004). Population codes: KL=Kootenay Lake, DL=Duncan Reservoir, KR=Kootenai River, KT=Kootenai River, LKR=Lake Roosevelt, CJS=C. J. Strike Reservoir, CRE=Columbia River estuary, LFR=Lower Fraser River, MCN=McNary Pool, NKO=Nechako River, SAC=Sacramento River.

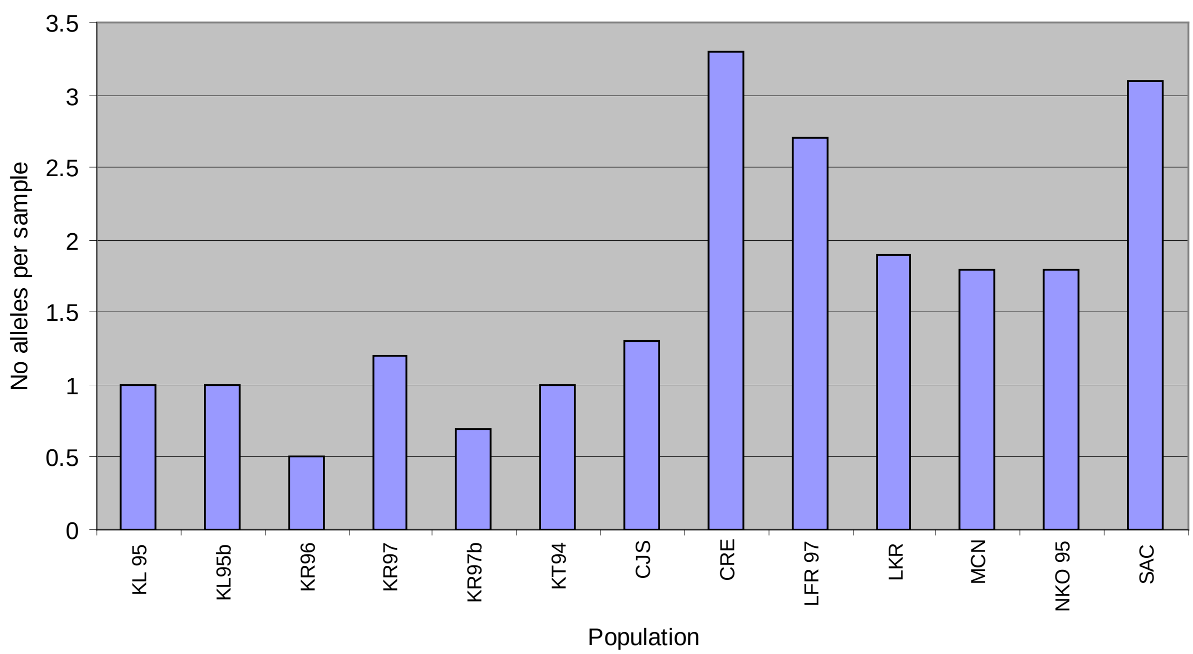


Figure 18. Number of alleles per sample by population or sample group where n>10, comparing genetic variability among Kootenai River, Kootenay Lake, and other white sturgeon populations from throughout the species range. Population codes: KL=Kootenay Lake, KR=Kootenai River, KT=Kootenai River, LKR=Lake Roosevelt, CJS=C. J. Strike Reservoir, CRE=Columbia River estuary, LFR=Lower Fraser River, MCN=McNary Pool, NKO=Nechako River, SAC=Sacramento River.

Microsatellite marker suites, analyses, and sample collections have been improved considerably since these early 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.

At larger spatial scales, the weak genetic differentiation observed 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 and gene flow (genetically effective migration) for white 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 (McPhail and Lindsey. 1986). White sturgeon historically had free range to move throughout the system. Although 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, it may also be due to its central location in the species range, and the increased ability to receive genetic material (gene flow) from the Sacramento and Fraser rivers (Anders and Powell 2002).

Although the extent that current patterns reflect historical conditions is uncertain, current population genetic data can be useful to guide and evaluate restoration and recovery actions. Current population segments may not represent historical conditions. We know that overfishing during the late 1800s substantially reduced effective population sizes and that dam construction since the 1930s has fragmented white sturgeon in the Columbia basin and replaced bi-directional gene flow, the natural source of genetic variation, with predominantly downstream gene flow (Jager et al. 2001). Sturgeon movements in the Columbia River mainstem reservoirs 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). With the exception of the East Ladder at the Dalles Dam, upstream movements (Warren and Beckman 1993), though possible at some dams, are uncommon throughout the FCRPS (North et al. 1993; Parsley et al. 2007). Genetic diversity of many impounded populations is threatened by small effective population sizes due to low abundance, the sturgeon maturation cycle, and environmental patterns that may present infrequent opportunities for successful reproduction and recruitment.

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 or relocation activities (e.g. broodstock selection, effective population sizes and mating protocols). In the 2010 Lower Columbia and Snake River Sturgeon Workshop, 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. Workshop discussions highlighted the difficulty of attempting to delineate distinct units where the genetic diversity graduates clinally from the river mouth to headwaters. Five genetic management units were identified consistent with recommendations of the workshop participants (Figure 19). Boundaries of the mid-Columbia unit were drawn overlapping adjacent units to reflect the observed gradation in genetic characteristics from area to area. Nonetheless, with the possible exceptions of these overlapping MU boundary areas, genetic signatures of white were more similar within than between MUs.

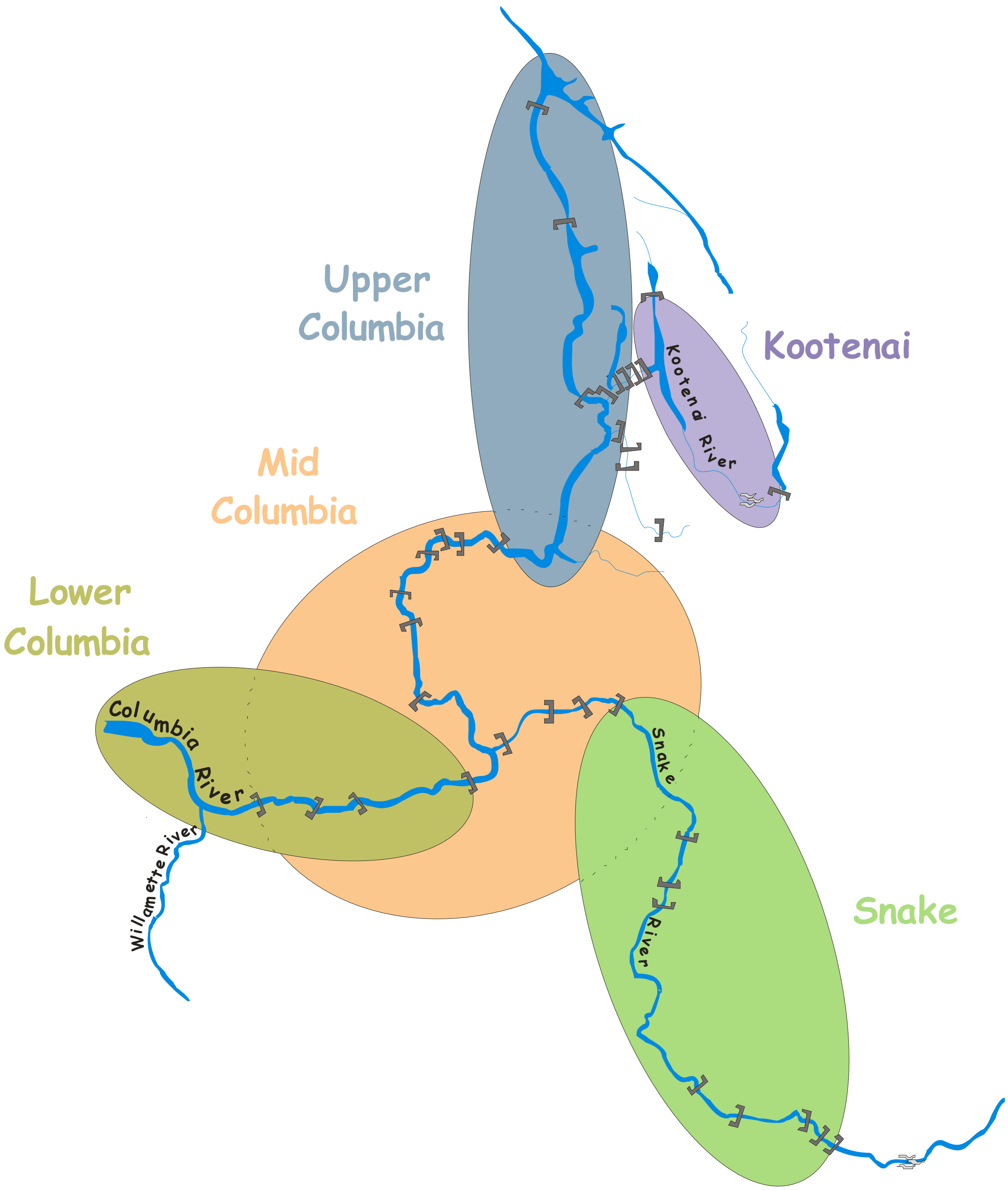


Figure 2. The five Columbia Basin White Sturgeon Genetic Management Units (GMUs).

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 a small portion of their historical range. Numbers and distribution are continuing a long-term decline in many areas as natural production is no longer adequate to replace remnant populations.

3.1 Distribution and Spatial Structure

In the Columbia River basin, white sturgeon historically had potential access from the ocean to Windermere Lake in the upper Columbia River and to Shoshone Falls in the upper Snake River. The Kootenai River population has been physically 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 have 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 an admixture of anadromous and resident life histories, with the incidence of anadromy presumably decreasing with increased upstream distance from the estuary. Subpopulations in the upper reaches of the basin most likely 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; Hildebrand and Parsley 2013). Distribution in far inland locations may have been patchy, with fish likely concentrated in areas of favorable habitat and food resource availability.

White sturgeon in the Columbia River basin consist 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 dams (Jager et al. 2001). 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 20). 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.

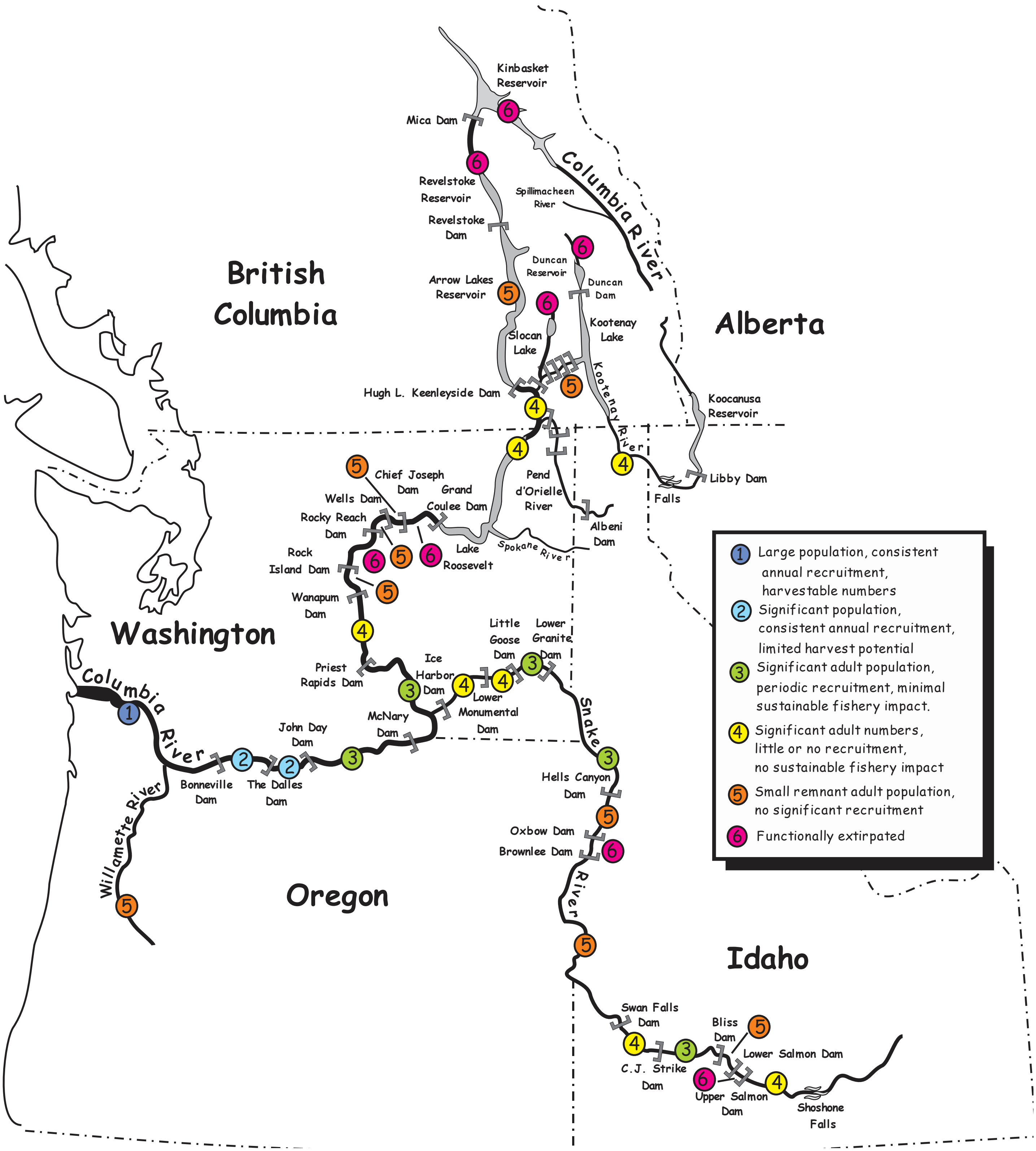


Figure 20. Distribution and status of Columbia Basin white sturgeon subpopulations.

3.2 ABUNDANCE

Exact historical numbers of 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 (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 standing stock and collapsed by the late 1890s. However, harvest numbers represented a minimum estimate of adult sturgeon abundance at that time because not all harvest was accounted for and not all fish were harvested.

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 in 1950 that allowed harvest of fish between 30 and 72 inches total length. The harvest regulation was changed to 36-72" TL in 1958 and 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, which 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 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 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, from 442 in 2006 to 2,172 in 2010 (Tackley et al. 2008a, 2008b; Stansell et al. 2010.

Abundance of sturgeon upstream from Bonneville Dam is much less than in the lower river. Numbers vary considerably from subpopulation to subpopulation but generally decrease 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 harvest. In order to ensure sustainable fisheries and optimize harvest in these three reservoirs, population assessments are completed in each of these three reservoirs over a three-year rotating cycle.

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		**515,582**		
	Bonneville	333,423	> 20 in. FL (2009)	Chapman et al. 2012
	The Dalles	133,260	> 20 in. FL (2008)	Chapman et al. 2012
	John Day	40,649	> 20 in. FL (2010)	Chapman et al. 2012
	McNary	8,250	> 20 in. FL (1995)	Chapman et al. 2012
U. Mid-Columbia		**756**		
	Priest Rapids	134	> 28 in. FL (2002)	
	Wanapum	551	> 28 in. FL (2002)	GCPUD 2008
	Rock Island	4	1 pass; 4 fish (1998)	
	Rocky Reach	29	> 28 in. FL (2001)	GCPUD 2008
	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)	DeVore et al. 1998
	Lower Monumental	4,260	>20 in. FL (1997)	DeVore et al. 1999
	Little Goose	6,490	>20 in. FL (1997)	DeVore et al. 1999
Middle Snake		**7,538**		
	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

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 periodically 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 (Golder 2005; Howell & McLellan 2007). Only about 50 fish are estimated to remain in Arrow Lakes upstream from Keenleyside Dam and only a handful of individuals are thought 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 released 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 that were in the Kootenay Lake. However, this wild population continues to dwindle. A conservation aquaculture program has 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.

3.3 Productivity

The white sturgeon population in the Columbia River downstream from Bonneville Dam has been 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 the 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. Current 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, and when 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 (Figure 21) (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, and “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.

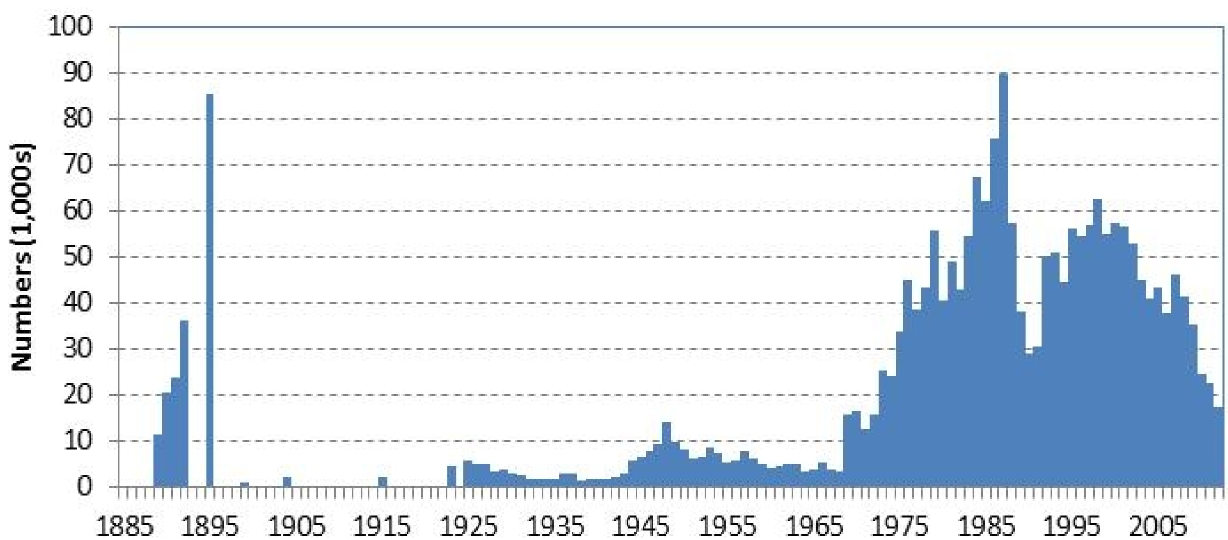


Figure 21. Historical harvest of white sturgeon in lower Columbia River fisheries.

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 (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% of the harvest slot size 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 adopted similar rules, prohibiting white sturgeon retention in the lower Columbia River, Washington coast, Puget Sound, and tributaries, effective January 2014. 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 incorporated a conservation buffer, reducing the harvest rate by 10% (OFWC guidance) to 25% (WFWC guidance). The Directors agreed to reduce the harvest rate by 15%, to 13.6% for 2013. The Commissions also adopted separate guidance reducing the recreational fishery annual personal use limit, from 5 fish to 1 fish in Oregon and to 2 fish in Washington. Both Washington and Oregon adopted a 2-fish statewide annual

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 Zone 6. 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 annually 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 and Ice Harbor Dams

Retention of white sturgeon is allowed in recreational fisheries from McNary Dam upstream to Priest Rapids and Ice Harbor dams from February through July. This retention season was adopted in 2010. Prior to 2010, sturgeon retention was allowed year-round. A 48-inch minimum size limit restriction was implemented in 1991 to manage harvest of fish in these populations. Time and area closures, adopted in 2010 to protect spawning and post-spawning sturgeon, are located immediately downstream from Priest Rapids and Ice Harbor dams.

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.

Upper Columbia

Angling for sturgeon on the upper Columbia became popular in the mid-1970s and this popularity increased steadily into to the 1990s. Sturgeon were one of the species targeted by guiding outfits on the upper Columbia River during in the late 1980s. However, 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 in 1996 with protective regulations in Canadian and U.S. sport fisheries and by voluntary reductions in subsistence harvest by First Nations people (UCWSRI 2002).

Lower Snake River

Retention of white sturgeon is allowed year-round in recreational fisheries from Ice Harbor Dam upstream to Lower Granite Dam. A 48-inch total length minimum size limit restriction was implemented in 1991 to manage harvest of fish in these populations. Washington converted to a fork-length standard in 2009 and the current size-slot for retention of sturgeon in the lower Snake River is 43-54 inches fork length.

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 length. 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). Kootenai River white sturgeon were harvested at various rates during the 1900s until all fishing for the species was prohibited in Montana in 1979 and Idaho and British Columbia in 1994; the population was listed as endangered in the US in 1994 (USFWS 1994, 1999).

4.2 CURRENT FISHERY TYPES & AREAS

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 was in excess of 25,000, harvest in the past three years (2009-2011) has declined annually and only averaged 16,380. The annual 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 from Bonneville Dam. Total non-Indian recreational harvests in the lower Columbia, inclusive of the Willamette River, 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.

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.

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).

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 per year.

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	451	396
2003	31,932	2,175	34,107	7,947	1,437	325	301	228
2004	28,443	1,611	30,054	7,866	1,748	269	323	186
2005	30,904	1,106	32,010	8,152	1,741	311	229	228
2006	26,394	962	27,356	8,312	860	201	202	154
2007	35,136	1,039	36,175	7,761	1,124	161	307	192
2008	29,496	1,134	30,630	7,859	1,588	226	356	307
2009	23,829	1,000	24,829	7,737	1,618	219	238	352
2010	14,116	1,946	16,062	4,385	3,026	616	140	480
2011	11,195	3,097	14,292	3,387	3,901	652	215	271
2012	7,860	2,585	10,445	1,922	4,546	447		

Non-treaty Subsistence

Non-treaty tribal sturgeon harvest rights also exist for subsistence and ceremonial (cultural) purposes. One such example is the Kootenai Tribe of Idaho, whose members have voluntarily foregone cultural or subsistence harvest of Kootenai River sturgeon.

4.3 Harvest Guidelines, Yield, Exploitation & Effort

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% of fish in the harvestable slot size, whichever was less; however, following the 2011 population estimate the Accord was modified and harvest rate was reduced to the 16% 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%; however, due to the modifications in the Accord, the guideline dropped in 2012. The 2013 guideline will be determined following the 2012 stock assessment.

Currently, white sturgeon harvest in lower Columbia River commercial fisheries is managed to distribute landings throughout the year to maximize economic benefit and help distribute the catch throughout the five commercial fishing zones (Figure 22). Commercial fishing seasons occur during winter (January-mid March), spring (late March-mid June), summer (mid-June-to 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 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.

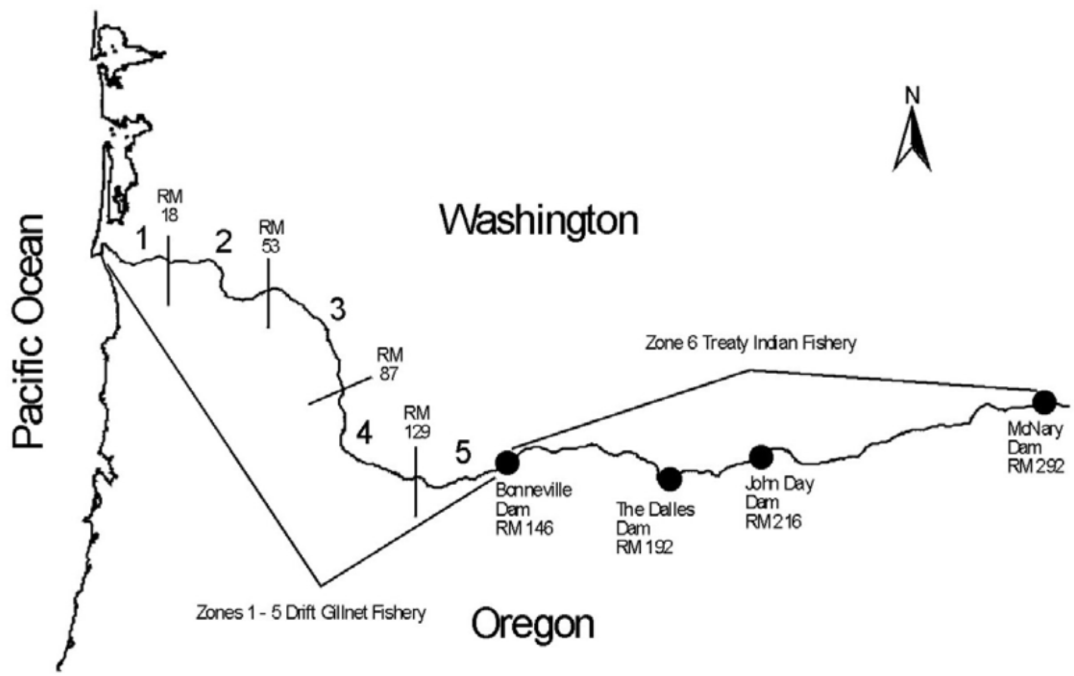


Figure 22. Map showing commercial fishing zones of the Columbia River from the mouth to McNary Dam (ODFW 2011).

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 yearlong 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 (conservation) 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 August 31 to protect spawning white sturgeon.

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. After a spike in harvest during the mid to late-1980s harvest has generally leveled off or declined, with a slight increase from the mid-1990s to the mid-2000s (Figure 23). Harvest remains far greater in the lower river than in the Zone 6 fishery (Figure 23, inset chart).

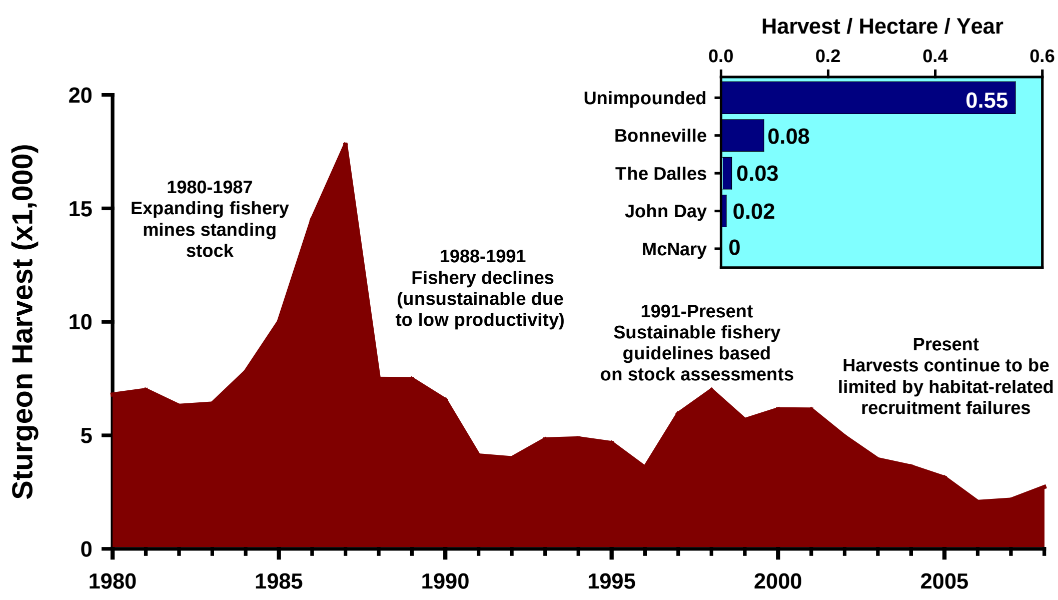


Figure 23. Annual harvest of white sturgeon from lower mid-impoundments upstream from Bonneville Dam and relative productivity based on 2008 harvest guidelines which are derived from sustainable harvest rates at current population levels (data from NPCC 2004; ODFW & WDFW 2008; Mallette 2008).

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.

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 (Table 7). 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 anglers 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.

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.

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

Year	Bonneville Pool		The Dalles Pool		John Day Pool	
	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

Columbia River upstream of McNary Dam

Sturgeon harvest in the McNary Pool is limited to recreational fisheries since treaty fisheries are restricted to Zone 6. 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. Harvest has averaged 236 fish per year since 2002 (range: 122-378) (Table 6).

The Priest Rapids sturgeon spawning sanctuary extends from Priest Rapids Dam downstream approximately 2.5 miles to the boundary marker on the riverbank 400 feet downstream of the Priest Rapids Hatchery outlet channel (Jackson Creek). The area that is closed to all fishing for sturgeon from May through July to protect spawning and post-spawn fish. A similar May through July no-fishing sanctuary extends 1.5 miles downstream from Ice Harbor Dam on the Snake River.

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 1996 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.

Lower 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. Harvest has averaged 279 fish per year since 2002 (range: 154-480) (Table 6) and is similar in magnitude among the three populations, averaging 84 fish per year in Ice Harbor Reservoir, 86 fish per year in Lower Monumental Reservoir, and 110 fish per year in Little Goose Reservoir. These levels are similar in magnitude to estimates for the preceding 14-year period, when an estimated 53, 80, 116 fish were harvested per year respectively from Ice Harbor, Lower Monumental, and Little Goose reservoirs (WDFW data). The area below Ice Harbor Dam is closed to fishing from May 1 to July 31 to protect spawning adult white sturgeon.

Middle Snake River

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.

Kootenai River/Kootenay Lake

Kootenai River white sturgeon were harvested at various rates during the 1900s until all fishing for the species was prohibited in Montana in 1979 and Idaho and British Columbia in 1994 (USFWS 1999). Although non-treaty tribal sturgeon harvest rights exist for subsistence and ceremonial (cultural) purposes, the Kootenai Tribe of Idaho has voluntarily foregone cultural or subsistence harvest of Kootenai River sturgeon in support of population restoration and recovery.

5 OVERVIEW OF LIMITING FACTORS & THREATS

Several factors and threats greatly influence the health of white sturgeon populations in the Columbia Basin. 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 negative effects from the limiting factors.

5.1 HABITAT FRAGMENTATION

While dam construction was not directly responsible for the historical decline of white sturgeon throughout the Columbia Basin, 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 capable of complete admixture, being 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 (Jager et al. 2001; Anders et al. 2002; Parsley et al. 2007; Drauch Schreier et al. 2013).

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 et al. 2001, 2006a, 2006b). 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 24). 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.

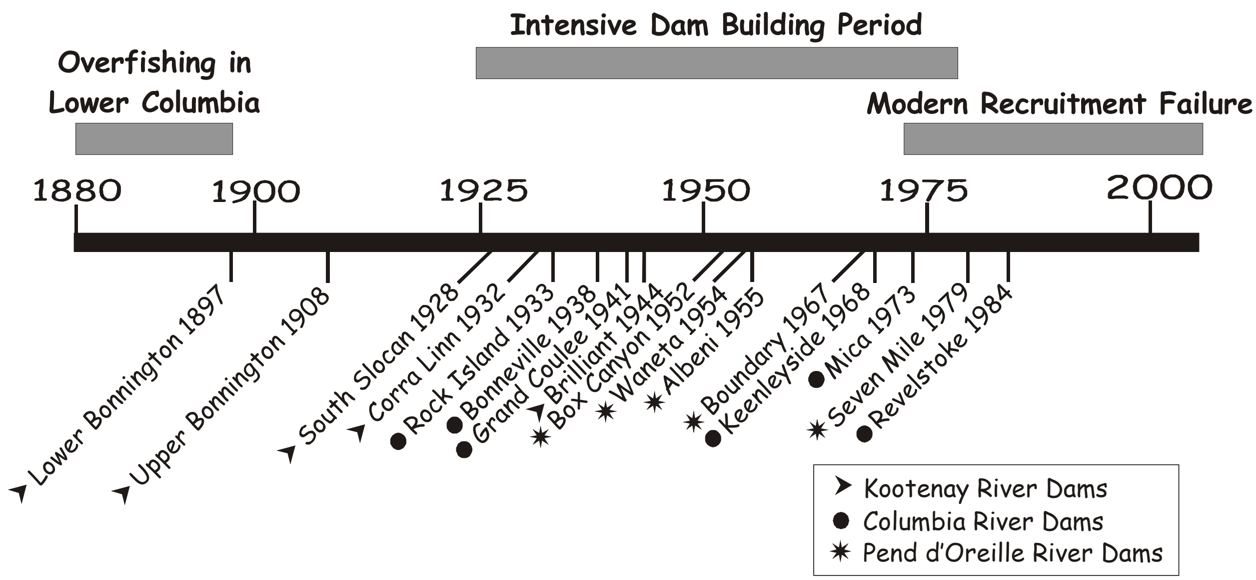


Figure 24. Time line of dam construction and white sturgeon impacts affecting upper Columbia River basin white sturgeon.

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 may reduce salmon passage success.

5.2 Habitat Complexity, quantity and Quality

Riverine habitat structure complexity, and quality have been substantially altered by impoundment, channel modification, flood control, and flow regulation throughout the Columbia River basin. Substantial habitat diversity was lost as a result of impoundment. Changes in river geomorphology, hydrology and resulting hydraulics as a result of flood control and flow regulation are no less significant. Historical floods helped maintain channel diversity by periodically scouring and rearranging materials to create and reconnect pool and backwater habitats. Today, regulated flows result in a more uniform river channel and armoured embedded substrates. 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 and thermal conditions at potential spawning and nursery areas, and alter substrates in incubation and rearing habitats necessary for survival of early life stages (Partridge 1983; Apperson and Anders 1991). Complex habitats can provide increased diversity and abundance of seasonal forage production and refuge 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 (Coutant 2004).

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). A recent study by Parsley et al. (2010) involving subadult white sturgeon habitat use locations and responses to river channel dredging in the Lower Columbia River showed that the rates of movement, depths used, and diel movement patterns showed little change over all periods, suggesting that natural behaviors were not altered during and immediately after hopper dredge disposal operations. 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 effects 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.

Much farther upstream, habitat simplification and isolation of off-channel and backwater habitats have been particularly severe in the Kootenai River, where historical functions of this large river-floodplain ecosystem are now isolated from the historic floodplain (Anders et al. 2002; KTOI and MFWP 2004). Following extensive levee construction and impoundment by Libby Dam, altered flow (spring ½ of historical; winter increase 300%, lack of flushing flows) extensive loss of side channel, wetlands and floodplain connectivity, altered sediment transport and deposition and scour, and altered water flow and resulting in-channel hydraulics (affecting, bed morphology, depth, velocity, and nutrient and sediment provision) have been cited as factors endangering this listed population (USFWS 1999; Duke et al. 1999; Anders et al. 2002, 2013). IN response to these changes, the Kootenai Tribe of Idaho is implementing a series of large-scale habitat improvement and reconnection projects designed to improve habitat quality, connectivity, and along with an ongoing nutrient addition, improving biological production (KTOI 2009; S. Young KTOI personal communication 2013)

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, post-impoundment 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 ($\geq$ 1 mps; 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 has been positively correlated with 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 reduced discharge from Bonneville Dam (van der Leeuw et al. 2006). Flows during spring and early summer (the spawning time of white sturgeon in the Columbia River basin) have been positively correlated with recruitment of Age-0 white sturgeon in the lower Columbia River (Parsley and Beckman 1994). However, recruitment even the YOY stage is a multi-stage process involving survival through a series of sensitive early life stages that requires more than suitable hydraulic conditions during spawning and early life periods (Anders et al. 2012, 2013).

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). However, no flow measures have been implemented to date for the specific benefit of impounded sturgeon populations in the mid-Columbia and lower Snake rivers. Likewise, specific flow measures implemented at Libby Dam to help restore natural production of Kootenai River white sturgeon have also failed to produce any consistent observable results for spawning behavior, success and recruitment (USFWS 1994, 2011), where restoration of natural recruitment appears to require more than altered river flows (Anders et al. 2002, 2013).

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 25). However, this location also contains the most abundant population throughout the species range. 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 and in part maybe due to smaller number of spawners available during any particular year.

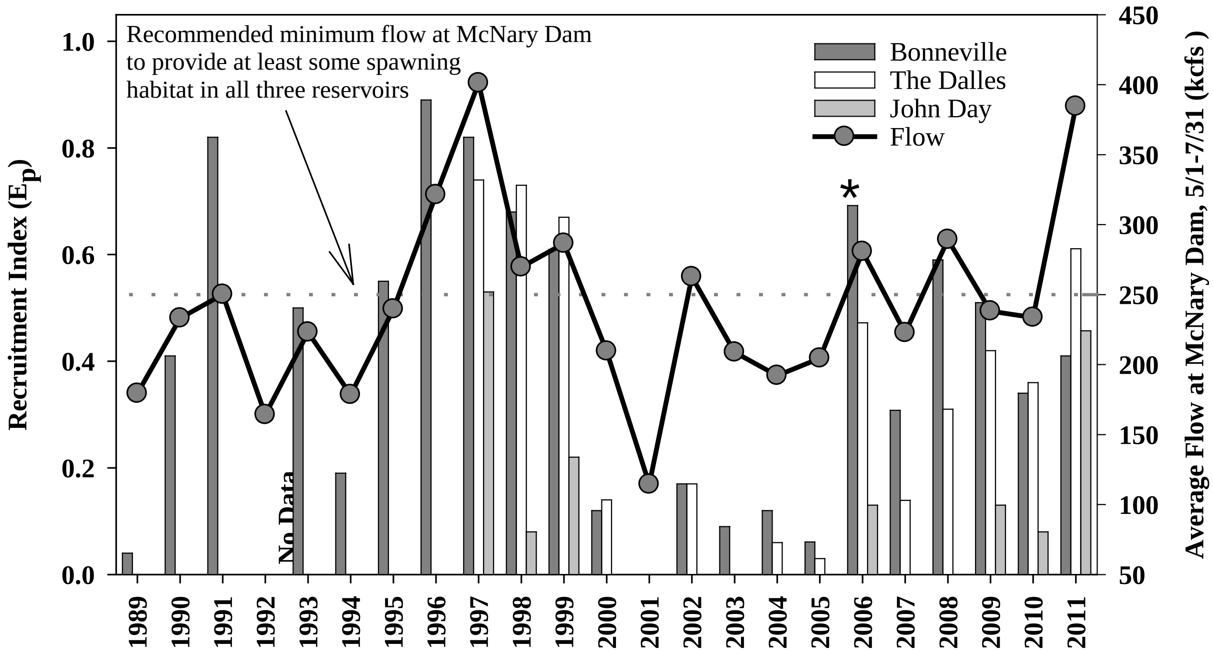


Figure 25. Recruitment index (Ep) for white sturgeon in Bonneville, The Dalles, and John Day reservoirs, and average daily flow at McNary Dam (May-July). *In 2006 age-0 indexing in Bonneville Reservoir switched from USGS trawl surveys to ODFW/WDFW/CRITFC gillnet surveys.

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 synchronized suitable temperature, flows, and available habitat (substrate) conditions needed for successful spawning and early life survival. Libby Dam operations on the Kootenai River in Montana have been modified since the early 1990s to provide additional discharge and more natural thermographs, and more specifically during recent years to improve conditions for sturgeon spawning and early rearing under a BiOp RPA (USFWS 2006). However, to date no natural production responses have been observed (USFWS 2001; P. Rust, IDFG and J. Flory, USFWS personal communication 2013).

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 and bioaccumulation through the food web. Longevity, late maturation, benthic habitats, and position at the top of the food web 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, benthically oriented species, they have increased opportunities for exposure to and bioaccumulation of contaminants. Although 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), 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).

Impoundment 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.

Exposure to contaminants has been suggested to cause direct mortality of sturgeon larvae. Kruse and Scarnecchia (2002) suspected contaminant (copper and the PCB Aroclor 1260) exposure led to decreased survival of white sturgeon eggs. Sand-sized water-granulated fumed slag released from the Cominco Ltd. (now Teck Metals Corporation) lead and zinc smelter in Trail, British Columbia is distributed throughout the Roosevelt Reach, but primarily in the upper portion with a major depositional area at Marcus (CH2M Hill and Ecology Environment, Inc. 2006). Slag contains elevated levels of several trace elements, such as arsenic, cadmium, copper, lead, and zinc (Majewski et al. 2003). Preliminary acute toxicity studies with larval (30 dph) white sturgeon indicated LD50's at much lower concentrations of copper (3.1-4.9 µg/L) than similar aged rainbow trout (USFWS 2008). However, Vardy et al. (2011) reported that chronic concentrations (LC20) for white sturgeon larvae (up to 66 dph) exposed to copper (5.5 µg L-1), zinc (112 µg L-1), and cadmium (1.5 µg L-1) were similar to other sensitive salmonids. Smelter effluent which contained lead (mean=21.6 µg L-1 at 100%), zinc (mean=166 µg L-1 at 100%), copper (mean=2.5 µg L-1 at 100%), and cadmium (mean=2.55 µg L-1 at 100%) was lethal to white sturgeon larvae (11-14 and 32-35 dph) at high effluent concentrations of 100% and 50%, but in low concentrations (1%) mortality did not differ significantly from controls (Bruno 2004). While there may be some direct mortality for exposure to metals, the annual catch of relatively large numbers of free embryos and early larvae suggest that acute toxicity is not the root cause of recruitment failure. Contaminant exposure may result in sub-lethal effects that reduce survival of sturgeon during early life stages.

Concern has also been raised about the physical effects of slag on sturgeon free embryos and larvae. Slag particles are glass-like and very angular (CH2M Hill and Ecology Environment, Inc. 2006). It has been suggested that contact with slag could result in physical trauma to white sturgeon early life stages. Evidence of early larvae incidentally ingesting slag particles (attached to prey) has been confirmed through the examination of the gut contents of the D-ring plankton net catch (Howell and McLellan 2011) (Figure 10). Although, it is unknown if slag ingestion results in physical trauma or reduced survival of sturgeon larvae.

Juvenile white sturgeon in the upper Columbia River also ingested slag particles. Parsley et al. (2010) examined the gut contents of 37 hatchery origin juvenile white sturgeon captured in upper Lake Roosevelt (rkm 1,120 to 1,170) that had been at large for 1–4 growing seasons and 78% contained slag particles. Histological examination of the digestive tracts indicated significantly greater chronic inflammation relative to controls (fish reared without exposure to ingestible substrate). It is unknown if the inflammatory response would occur in sturgeons ingesting inert sand-sized substrate or if it results in reduced survival, growth, or condition. The relatively high survival, growth, and condition of hatchery sturgeon on the Transboundary Reach suggest that it does not.

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 in a controlled lab study setting. 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, 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. However, Kruse concluded that the contaminants studied were not present in amounts of concern in the Kootenai River.

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 or quantitative link between pollutants and contaminants and abundance has yet been established.

Turbidity

The construction of upstream reservoirs has drastically reduced river turbidity. Turbidity was historically high because of runoff from glacial systems and other natural large river processes. However, upstream reservoirs act as sediment and nutrient settling basins and have reduced sediment transport downstream. Changes in turbidity may have significant physical and biological 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. Spill at dams has caused supersaturation of atmospheric gas in waters of the Columbia, Snake, and Kootenai rivers and raises concerns about the effects of dissolved gas supersaturation (DGS) on white sturgeon. The timing and location of white sturgeon spawning and the dispersal of white sturgeon larvae from incubation areas makes them potentially vulnerable to the effects of DGS. To assess the effects of DGS on white sturgeon larvae Counihan et al. (2007) exposed larvae to mean total dissolved gas (TDG) levels of 118% and 131% saturation in laboratory bioassay tests. Gas bubble trauma (GBT) was manifested as a gas bubble in the buccal cavity, nares, or both, first occurring at developmental stages characterized by the formation of the mouth and gills. A 15 minute exposure was sufficient to elicit these signs in larvae in various stages of development. While no direct mortality was observed in larvae exposed to 118% TDG for 10 d, 50% mortality occurred after a 13-d exposure to 131% TDG. GBT was manifested as positive buoyancy and alterations in behavior that may affect the dispersal and predation vulnerability of white sturgeon larvae (Counihan et al. 1997).

5.5 Competition and Predation from Changes in Fish Communities

Predation

Pinnipeds

Predation on white sturgeon by Steller sea lions (*Eumetopias jubatus*), California sea lions (*Zalophus californianus*), and harbor seals (*Phoca vitulina*) 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 local densities and 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, from 442 in 2006 to 2,172 in 2010 (Tackley et al. 2008a, 2008b; Stansell et al. 2010; 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 primarily for early life stages of white sturgeon before age-1. In the estuary and ocean, predation on juvenile, subadult, and adult sturgeon, is also likely. This section discusses piscivorous fish predation on white surgeon at the egg, free embryo, larval, and juvenile life stages.

Eggs. 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. Such consumption rates suggest predation could be significant limiting factors in some cases for some populations.

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)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. Although it has been generally been assumed that beyond Age-0, white sturgeon body size and scute development appeared to function as successful anti-predatory mechanisms, juvenile hatchery reared white sturgeon up to 25 mm (TL) have been consumed by large (~ 4 kg) non-native walleyes in the Upper Columbia reach downstream from Keenleyside Dam (L. Hildebrand, Golder Associates, personal communication 2013).

Competition

The high fish content in the adult sturgeon diet suggests that they likely compete with other piscivorous fishes for food, and possibly over wintering habitat in some areas. These piscivorous fishes potentially include adult bull trout (*Salvelinus confluentus*), burbot (*Lota lota*), northern pikeminnow, and prickly sculpin (*Cottus asper*) (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 (*Richardsonius balteatus*). 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 undoubtedly 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 (Kime 1995).

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 the basin (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 narrower suitable 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; Anders and Beckman 1993). In the Kootenai River, white sturgeon spawn in May or June; however, water temperatures are much cooler, about 8° to 9° C, and spawning generally 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). In addition to earlier initiation of spawning, increased thermal units could also shorten the duration of the spawning window.

6 FRAMEWORK COMPONENTS

This chapter describes a comprehensive vision, goals, and strategies for sturgeon encompassing all areas throughout the basin. These overarching Framework elements were initially identified in a 2009 workshop focused primarily on sturgeon issues in the lower Columbia River and Snake River and have been revised somewhat to reflect the broader focus of white sturgeon efforts throughout the Columbia River Basin.

These components represent 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 to help develop this White Sturgeon Framework for the Columbia Basin. Together, they applied a broad range of scientific, technical, and management expertise to identify opportunities for complementary planning, and to examine critical uncertainties and needs for integration of efforts within and among different areas.

6.1 VISION

The following 20 to 50 year vision for white sturgeon in the Columbia Basin was identified from a series of Columbia Basin white sturgeon workshops:

> *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 needs 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 specific 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 the 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 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 amount of angler effort and numbers 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 conducive to spawning and production 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 identifies several strategies 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 to achieve the Framework goals. Strategies focus on 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.

Improving Passage/Connectivity

Sturgeon are a highly mobile species that can take advantage of ever changing river conditions. Construction of the mainstem dams greatly restricted sturgeon movement, recruitment, and quality, quantity, and availability of habitat. What was once a single population, or a series or broadly overlapping metapopulations, is now a series of fragmented subpopulations largely trapped within reservoirs. Sturgeon in the lower Columbia downstream from Bonneville Dam still have access to the ocean, where that population remains large and productive. Populations in impounded reservoir and 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 defined 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 volitional inter-action and movement.
- Consider sturgeon passage criteria when refurbishing existing ladders and fish structures.
- Consider transplanting fish from areas of greater to lesser abundance 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, when they're using it, and whether passage would help meet that need (feeding and rearing benefits vs. spawning benefits).

Habitat Restoration

White sturgeon historically had the potential to range 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 coevolved life history strategies and behaviors 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, and other critical biological requirements. Efforts to improve sturgeon production in several of the different management units face similar issues and unknowns.

Alternatives

Flow

- Promote hydro system operations that improve natural production and recruitment
- Operate the FCRPS to provide flows consistent with aggressive non-breach hydro system operations
- Manage water budget to provide optimal spawning conditions and survival of early life stages
- Restore river flow pattern to natural hydrograph
- Minimize extremes in flow peaks and load during the white sturgeon spawning season and subsequent larval dispersal period

Contaminants

- 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
- Determine acute and chronic toxicity of contaminants of concern on all life stages of white sturgeon
- Identify and implement contaminant remediation actions

Physical habitat

- Develop and implement habitat and substrate restoration and improvement programs where needed to restore and optimize natural production and post-release survival of hatchery produced fish.
- Assess effects of hydro and dredging operations on habitat conditions, behaviors, and suitability to affected whiter sturgeon life stages on a project-, population, reach, or MU basis

Harvest Management

While there is an adequate system in place to account for removals associated with recreational and commercial harvest in the lower river and in Zone 6, 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, delayed mortality associated with released fish, removals outside the Columbia River, and 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

Hatcheries

Hatcheries have been used to support commercial and recreational fisheries and to conserve imperiled populations (Campton 1995; Anders 1998). Successful conservation aquaculture 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 implemented to help achieve their objective of maintaining the natural genetic diversity of the population (number of alleles) and presumably reduce potential detrimental impacts of hatchery selection or domestication. To further increase genetic diversity and reduce the risk of hatchery selection or domestication, the Transboundary program in Washington and BC transitioned to the use of wild caught larvae in 2011 rather than traditional direct gamete takes from wild caught broodstock. Wild caught larvae from a single year represented substantially more alleles than in any year of traditional broodstock capture and was similar to the cumulative number of alleles over nine years of traditional broodstock capture (Schreier and May 2012). Recent efforts to rear and release wild caught and naturally produced larvae also promise for many new white sturgeon conservation aquaculture programs in the U.S. and Canada.

In addition, the role of sturgeon supplementation in meeting future recovery and harvest goals is one of the most significant decisions facing regional sturgeon managers and populations. 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). While maintaining a sustainable harvest, supplementation 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), or in situations when ongoing recruitment failure threatens population persistence. Initial hatchery operations in new facility or programs may be developed on an experimental basis, benefitting from previous decades of empirical experience and integrating lessons learned for older, existing programs while retaining the needed flexibility to address problems as they arise (i.e. managing adaptively).

In general, these hatchery programs are intended as interim stop-gap measures until natural recruitment can be restored. However, hatchery-produced sturgeon also enable critical applied research to determine limiting factors, habitat capacity, broodstock limitations, population parameters, and immigration/entrainment in natural populations, biological requirements, and innate behaviors not observable at the river scale (e.g. Kynard and Parker 2005a, 2005b; Kynard et al. 2010). Many questions regarding 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 rivers 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; Beamesderfer et al. 2012, 2013; Anders et al. 2013). 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 also provides a known subject population and structured releases allow for the design of systematic statistical experiments.

Alternatives

- Develop a standard step-wise protocol of genetic guidelines for consistent application to all white sturgeon hatchery programs in the Basin consistent with the identification and nature of the MUs and GMUs (e.g. Welch et al. 2010)
- Develop science-based hatchery programs to satisfy local and regional population abundance, genetics, and critical uncertainty research needs across the Basin while establishing sustainable sturgeon populations, MUs (management Units; Figure 4), and GMUs (genetic management units; Figure 10).
- Provide hatchery fish as experimental subjects for evaluating life-stage-specific limiting factors
- Release hatchery reared sturgeon at regular intervals in reservoirs to restore and maintain healthy age class structure at sub-population, MU and GMU levels
- Consider and where appropriate implement and evaluate a range of hatchery programs that may include spawning of wild gametes or broodstock, collection, rearting and release of wild embryos or larvae, and other options to adaptively address the range of recruitment and population management needs across the basin as dictated by specific sub-populations, MUs and GMUs

- Consider and where appropriate implement and evaluate management practices that use natural production, hatchery production, and some combination of the two approaches as dictated by sub-population conditions consistent with reach or sub-population-based productivity within MUs and GMUs
- Use selected pools or river segments to evaluate supplementation
- Where possible, strive to maintain a self-sustaining natural origin component of population capable of providing adequate broodstock for supplementation needs
- Produce white sturgeon in hatchery programs for release as juveniles into management areas
- Evaluate growth rates and the food base in each pool/river segment to determine proximity to carrying capacity and optimal stocking rates
- Establish and implement a common set of genetic management guidelines for all hatchery programs within the basin
- Complete microsatellite analysis of individual sub-populations, MUS and GMUs within the Basin to help develop a science-based approach to maintain and where appropriate, support local sub-populations
- Develop, implement, monitor, and evaluate effective hatchery techniques and genetic evaluations to enhance demographic and genetic components of sub-populations, GUs and MUs while evaluating abundance, condition, relatedness and other relevant performance metrics

6.4 Monitoring & Evaluation

Success in our efforts to improve Columbia and Snake River white sturgeon populations demands implementation of a strategic adaptive management (AM) process. Adaptive management allows managers to manage in the face of uncertainty and learn by doing. It helps us understand how and why fish populations and their associated habitats respond to different management actions, and use these findings to better address key limiting factors and threats. Although adaptive management is a rigorous, procedural scientific process, most "adaptive management" programs lack discreet details and the implementation of testable hypotheses and clearly stated actions taken in response to a suite of possible outcomes, the central components of central AM.

Alternatives

- Comprehensive RM&E program to assist with development and adaptive management of white sturgeon in management areas, incorporating specific issues, testing hypotheses, and sharing results
- Update population age structure, abundance, and recruitment assessments across the Basin frequently enough to determine baseline status and population trends, with special attention to populations currently lacking adequate data to determine status and trends

- Complete and periodically update individual population status ranking across basin/range
- 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, habitat restoration, and hydro operations
- Monitor and evaluate sources of natural and unaccounted mortality (delayed fisher impacts, illegal harvest, pollutants) mortality
- Monitor populations and model production scenarios requirements for population persistence and sustainable harvest rates
- Provide consistency in supplementation, broodstock, and monitoring and evaluation methodology with adequate flexibility to reach program or sub-population specific needs
- Continue to address various management questions with genetic analyses

6.5 Critical Uncertainties Research

Presently, much remains unknown about white sturgeon populations and habitats in various reaches of the Columbia Basin. Managers in several of the different management units face similar issues and uncertainties that may impact the long-term success of their efforts to conserve and restore white sturgeon populations within their respective MUs. Many of these unknowns and data gaps could best be addressed through a coordinated research, monitoring, and evaluation.

Alternatives

- Determine causes of recruitment or reproductive failure through testable hypotheses in each population
- Evaluate fecundity, productivity and survival of juveniles from various age fish to determine when or if significant reductions occur due to senescence
- Conduct sonic telemetry studies to determine seasonal movements and habitat use in diverse areas of their range to help understand their habitat needs in various reservoirs, especially during the winter work window for channel maintenance dredging activities.
- Research winter habitat use and distribution of sturgeon and their major food sources and the effects of dredging and in-water disposal. Some areas may be frequently disturbed for reservoir and shipping maintenance dredging and in-water disposal (such in upper Lower Granite Reservoir near the ports, etc.). This is a significant data gap in our knowledge to mitigate the effects of channel maintenance activities.
- Analyze contaminants in eggs

- Identify innate behaviors and habitat requirements for early life stages where limited mutual production or recruitment failure are occurring. Through replicated experimentation, use results to diagnose and guide conservation and management activities
- 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 a computer population model in three years with inputs and outputs for defining and managing a persistent population in each pool.
- Conduct maternal transfer of contaminants toxicity evaluations to determine possible influence on survival, fitness, growth.
- Evaluate carrying capacity in each pool through evaluations of spawning and juvenile production, 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

In terms of implementation, this Framework was designed to provide a series of alternative management actions as a guiding framework. These in turn should be further developed and refined at finer spatial scales by relevant regional and local entities. In that context regional alternatives are provided below to guide efforts to better conserve and manage white sturgeon within and among the MSs and GMUs identified in this Framework document:

- Use a science-based approach to implement a decision framework that integrates empirical data and information into collaborative and coordinated management decisions
- Create a permanent working group with representatives from state, federal, provincial, and tribal agencies to address management and propagation issues for all pertinent areas of the Columbia Basin
- Support development of 'technical teams' to facilitate information sharing and transmission to managers
- Conduct periodic progress briefings or meeting among collaborators to exchange information exchange, foster regional program interaction and impact resolution
- Secure consistent and stable long-term funding for monitoring in all areas, not just a few from all conceivable sources

7 MANAGEMENT UNIT SUMMARIES

This chapter discusses existing conditions, programs, and management directions in the nine identified management units for Columbia Basin and Snake River white sturgeon: 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)

Located in the geographic center of the species range, 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 downstream from Bonneville Dam are the only population segment in the basin with continued access to ocean and estuarine environments (Figure 26). As a result, the population has been able to maintain an amphidromous life history strategy, and to exchange demographic and genetic features 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.

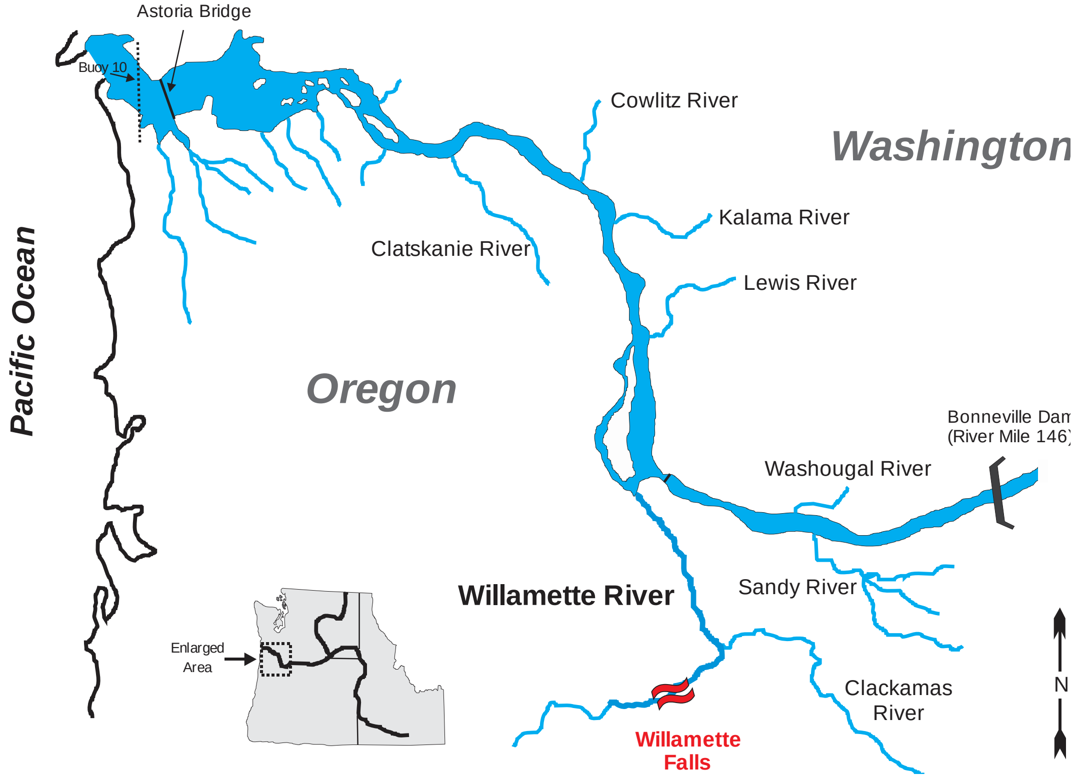


Figure 26. Map of the Lower Columbia management unit including the lower Willamette River.

Status

The lower Columbia River population is the most abundant and productive within the MU 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 the 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 useful for tracking abundance trends, but is less ideal for generating specific abundance levels. 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 current abundance, size structure, and abundance over time for 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 will to use to estimate future 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. 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 that past but 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, at 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			Setline method
	96-107 cm (38-43 in)	108-137 cm (43-54 in)	96-137 cm (38-54 in)	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

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

Table 9. Summary of biotic and abiotic limiting factors and affected white sturgeon life stages in the Lower Columbia River. Each factor, listed by abiotic or biotic, 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 "Low" 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	Low	Low	Med
Available Native Forage Species	Med	Med	Low	Low	Hi
Introduction of Non-Native Species	Med	Med	Med	Med	Med
Piscine Predation	Med	Low	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	Low	Hi	Hi	Hi	Med
Water Temperature	Med	Med	Hi	Med	Low
Sediment	Hi	Low	Med	Low	Low
Pollutants and Contaminants	Low	Med	Med	Med	Med
Dissolved Gasses	Hi	Low	Low	Hi	Low
Turbidity	Hi	Low	Low	Hi	Low
Fishing Effects	Hi	Med	Low	Low	Med
Incidental Hydrosystem Mortality	Med	Med	Low	Low	Med
In-Water Work Effects	Med	Low	Med	Med	Med

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; this trend may indicate a similar phenomenon.

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 were able to move 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, and 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), and average June discharge at Bonneville Dam has been decreasing since 1949 (Figure 27).

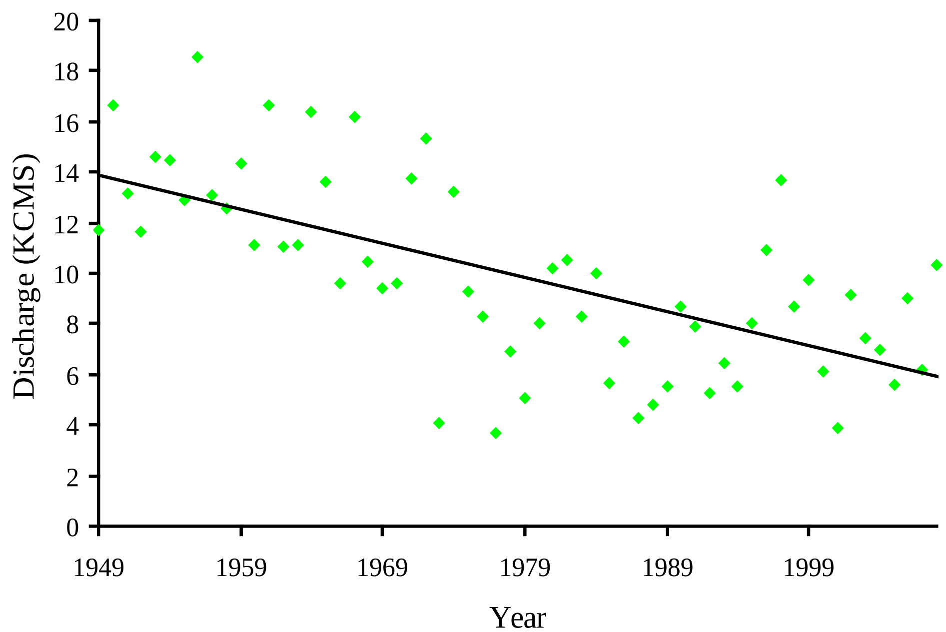


Figure 27. **Average June discharge at Bonneville Dam, 1949 through 2009.**

Water Quality

<u>Temperatures</u>

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 web. 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 may also affect incubation and dispersal of embryos, free embryos, and larvae. Although decreased turbidity in the Columbia River due to construction of the FCRPS undoubtedly increase predation related mortality for early life stages of white sturgeon, the actual magnitude and corresponding impact on the population is currently uncertain.

Fishery Effects

Lower Columbia River white sturgeon are subject to a variety of fisheries, and over-utilization can negatively impact the lower Columbia River white sturgeon population segment. If enough white sturgeon are removed, fewer white sturgeon reaching spawning sizes could reduce subsequent generations. Because of the monetary value of white sturgeon, particularly caviar, illegal harvest remains 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. 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 affect reproductive adults and thus, population productivity, either through direct mortality or decreased reproductive success (Schreck 2010; Webb and Doroshov 2011). Recent research revealed a strong positive correlation between "play time" and stress hormones 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 Washington Department of Fish and Wildlife and 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. Total illegal harvest numbers, including undocumented fish, 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 along with legal harvest could limit population productivity and sustainability. Because legal harvest is monitored and managed intensely, it is one of the few population metrics that are easily quantifiable. Therefore, the effects of harvest on the lower Columbia River white sturgeon population are better understood than many other limiting 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 a possible 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, considerable 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 after 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 sturgeon at a time at Bonneville Dam (B. James, WDFW, personal communication; USACE, unpublished data), though fish kills of this magnitude are rare. Mortality associated with most events are much smaller (on the order of one to two fish killed)although increased overall mortality occurs from repeated turbine start-up events (B. Hausmann, USACE, personal communication). Operational changes to minimize white sturgeon mortality should include a slow ramping up of turbine operations at all dams as feasible. 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 collection and relocation of any encountered fish) minimize mortality associated with these operational event (B. Hausmann, USACE, personal communication). Incidental hydrosystem mortality affects both spawning and rearing life stages. Although 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 occurs at night, is currently unknown (B. Hausmann, USACE, personal communication).

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, which the Washington Fish and Wildlife Commission endorsed. 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 Lower Columbia white sturgeon population plan is designed 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.

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 in an informal report documenting sturgeon mortality that 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.

Since 2004 researchers from ODFW have also used small mesh gill nets to document the 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. All collected 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 outside the Columbia River system have also 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 and August 2009 (Jones 2009). This stock assessment was repeated, with modifications to sampling design to incorporate a random selection of sites and increased 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 monitoring is to determine the number and yield of the fishery for each major commercial fishing zone.

A two-pronged approach is taken to accomplish this goal, including landing reports and creel surveys. 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 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 (Figure 28). 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.

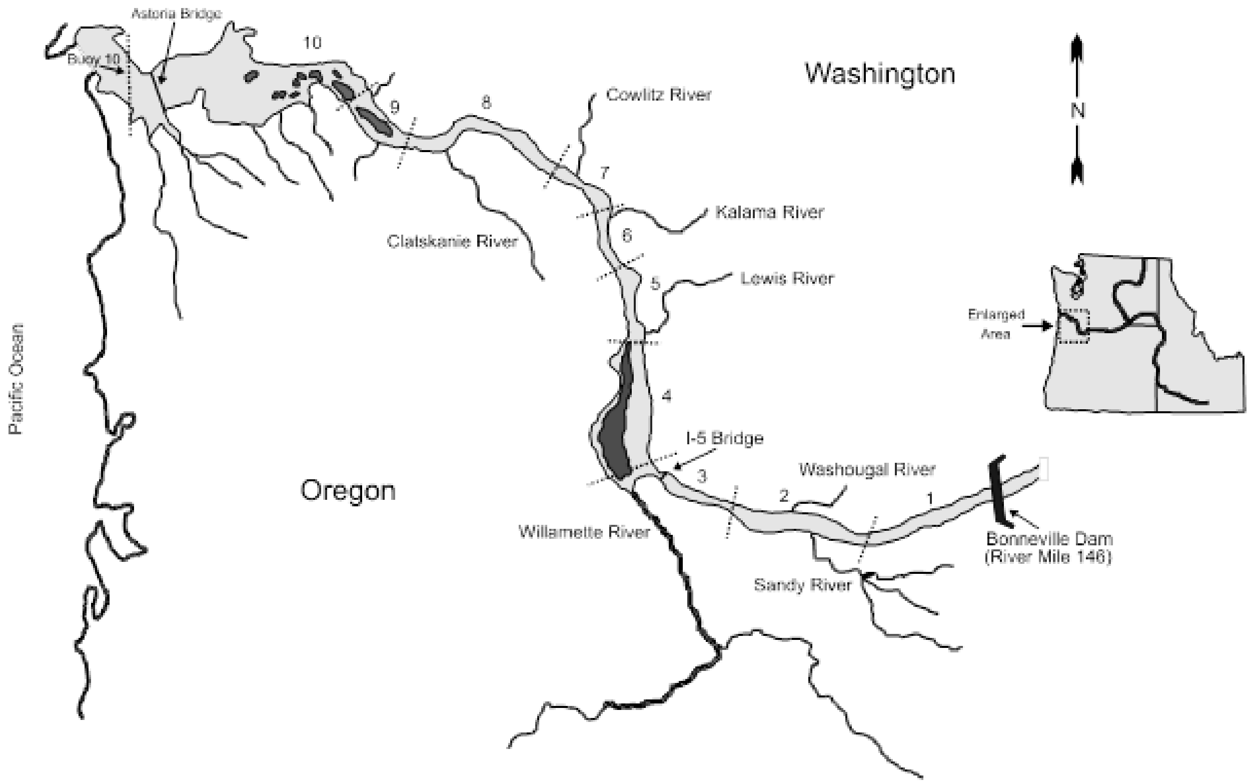


Figure 28. Recreational sampling sections of the Columbia River below Bonneville Dam.

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 in the Columbia River Basin primarily flood control and management of total dissolved gas) (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 primarily are intended 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).

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 and regional climate change and climate instability remain unclear. Global, regional, and local climate change and climate variability or instability 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 forecasted, the model generating the forecast has not been peer-reviewed.
- Declines in white sturgeon native forage species (e.g., Pacific salmon species, Pacific lampreys, and eulachon) from historic levels have been documented in the lower Columbia River and its 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 white sturgeon is composed of human and non-human sources of mortality. The extent of this mortality is currently unknown.

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

This management unit extends from Bonneville Dam to Priest Rapids Dam and includes Bonneville, The Dalles, John Day, and McNary reservoirs (Figure 29).

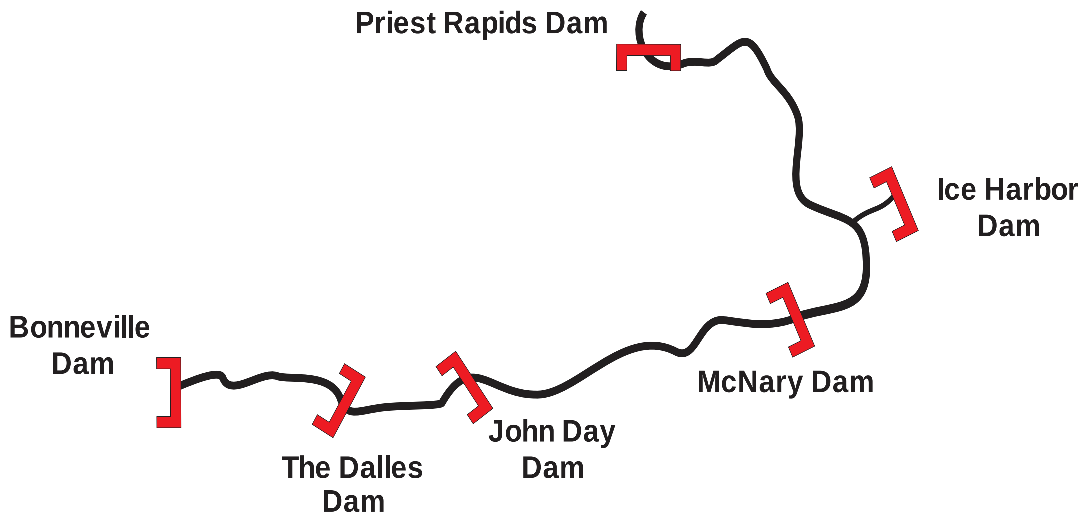


Figure 29. Map of the lower-mid-Columbia River sturgeon management unit.

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 (Table 10). 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 historical 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 creates high water velocities necessary where white sturgeon spawn (Parsley et al. 1993; McCabe and Tracy 1994). The amount of suitable spawning habitat has been correlated with discharge during the spawning cycle of white sturgeon (Parsley et al. 1993; Parsley and Beckman 1994). Because suitable spawning habitat and velocities may be limited, especially during low water years, water storage for flood control, power generation, irrigation and recreational use, habitat has created high levels of recruitment variability in the furthest downstream impounded populations, with little or no measurable recruitment occurring over several years (Table 11)(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)	Number of fish by total length interval (inches) 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

[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.

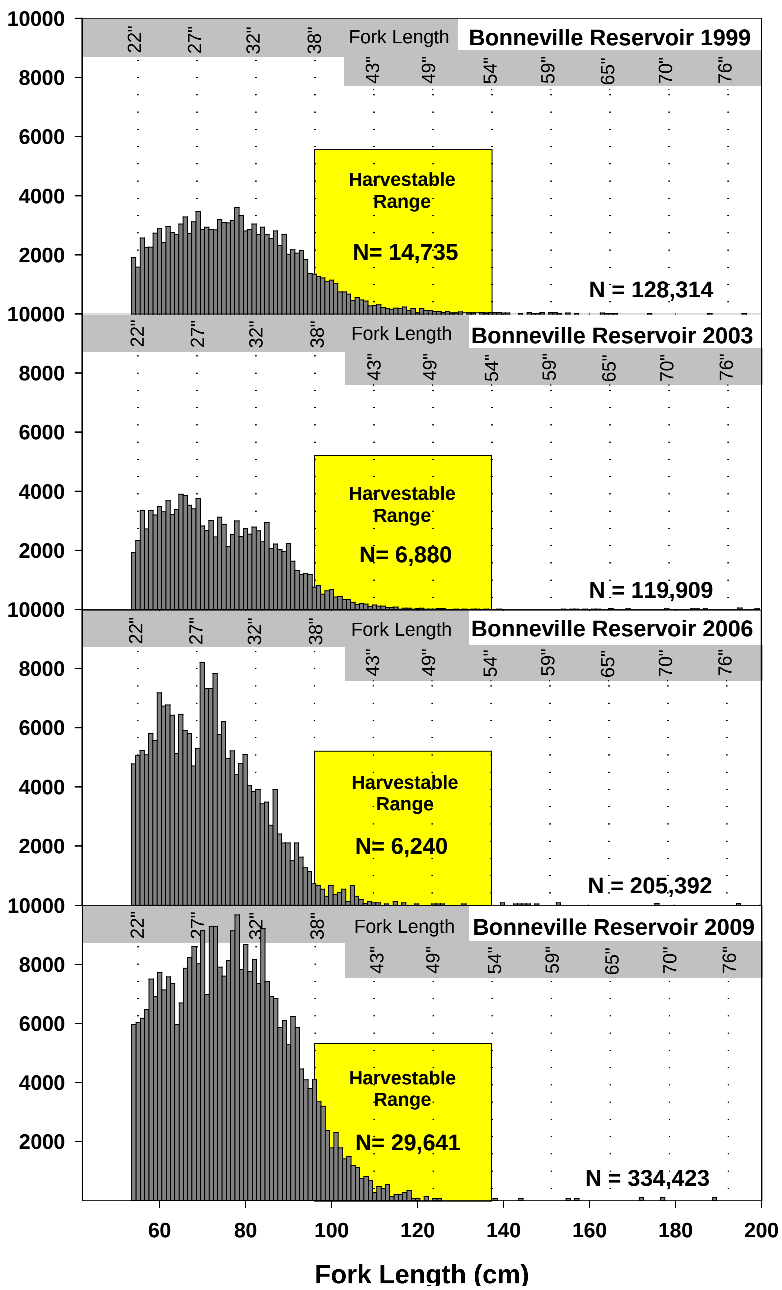
[c] Total poundage is estimated by multiplying total abundance (40,649) by median weight (8.4 kg or 18.48 lbs) of sturgeon caught with setlines in sampling periods 2 and 3.

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.

	Reservoirs			
Year	Bonneville	The Dalles	John Day	McNary
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 farthest downstream 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 30). 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

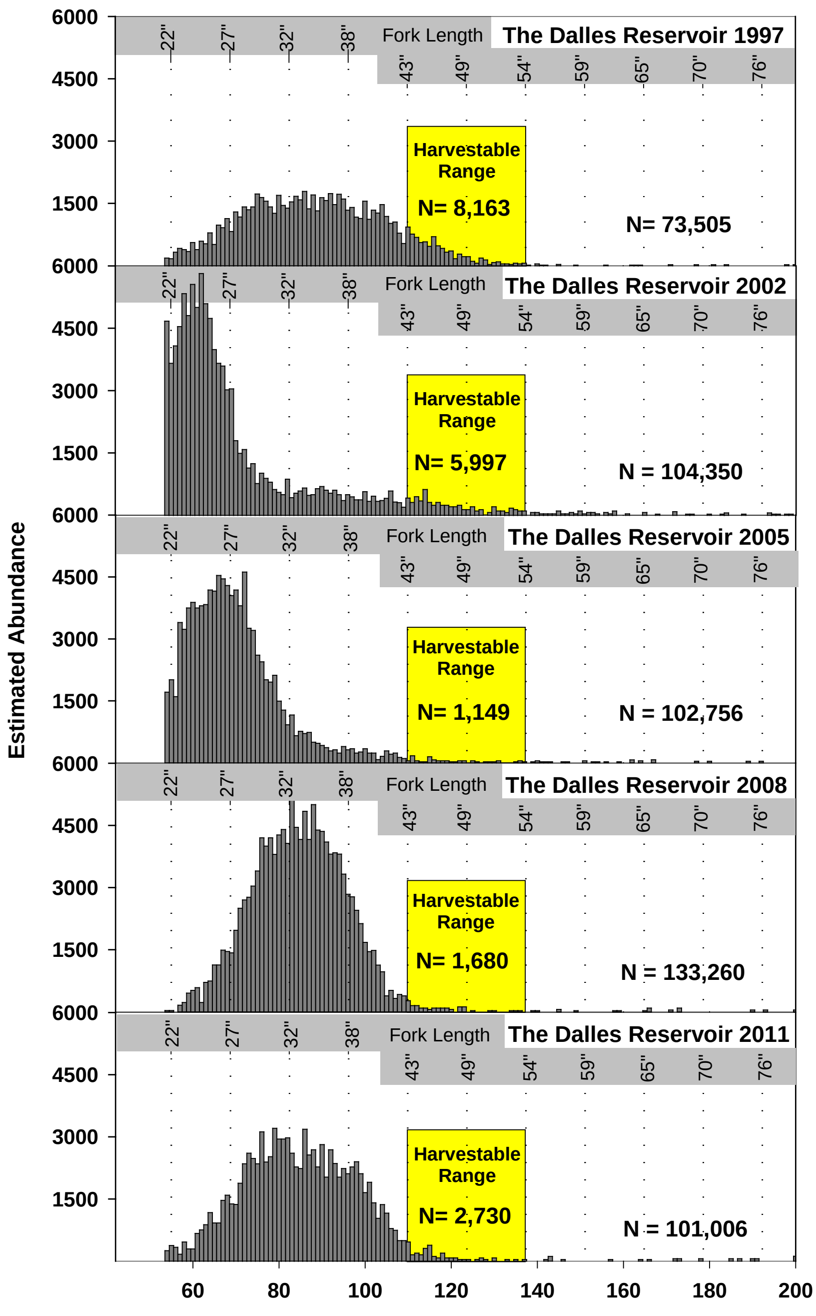
in TL	Abund
24-35	166,887
36-47	37,315
48-59	592
60-71	355
72+	243

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

Figure 30. Abundance estimates for white sturgeon (≥24 in total length) in Bonneville Reservoir, 1999-2009. (Data from…)

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 31). 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.



in TL	Abund
24-35	26,461
36-47	38,503
48-59	8,147
60-71	202
72+	191

in TL	Abund
24-35	82,950
36-47	13,532
48-59	5,926
60-71	1,166
72+	776

in TL	Abund
24-35	89,631
36-47	11,122
48-59	1,125
60-71	465
72+	414

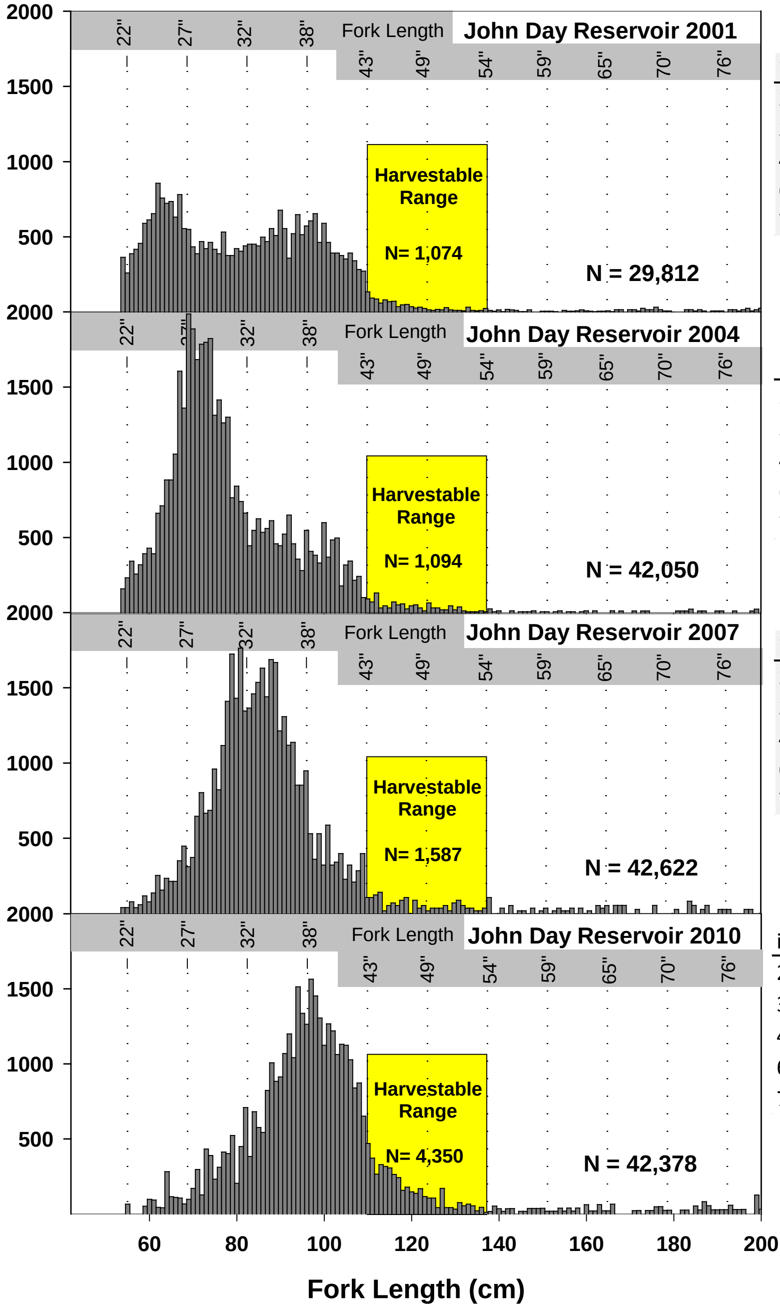
in TL	Abund
24-35	51,561
36-47	78,887
48-59	1,650
60-71	240
72+	921

in TL	Abund
24-35	42,097
36-47	54,866
48-59	2,730
60-71	269
72+	1,044

Figure 31. Abundance estimates for white sturgeon (≥24 in total length) in The Dalles Reservoir, 1997-2011.

John Day Reservoir

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), its white sturgeon population is characterized by a relatively low abundance of older, larger individuals (Figure 32). 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 (<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.



2001:

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

2004:

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

2007:

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

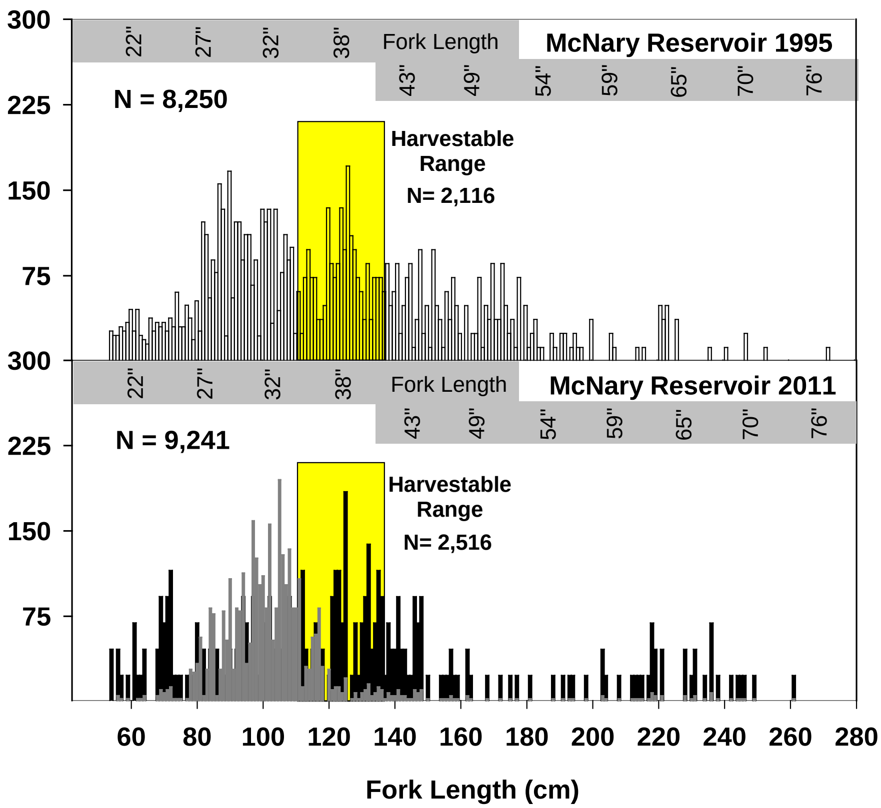
2010:

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

Figure 32. 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 its relatively large size of this reservoir (45,500 surface acres), the white sturgeon population in McNary Reservoir 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 33). 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 (<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 33. 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.

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 with 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 (Miller and Beckman 1996; Anders et al. 2002; Gadomski and Parsley 2005a, 2005b), the frequency and impact of this predation on white sturgeon at various life stages are poorly understood. Marine mammal predation on sturgeon occurs in this reach, upstream from Bonneville Dam, but at considerably lower rates than in the lower river downstream.

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 (*Oncorhynchus* spp). and steelhead (*O. mykiss*) 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 habitat 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 naturally produced 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. Warren and Beckman (1993) generally documented little movement among reservoirs with the exception the upstream movement of hundreds of subadult sturgeon at The Dalles Dam East ladder based on summaries of Fish Passage Center ladder count data.

Results from these studies suggest a net downstream movement of white sturgeon among the Lower Columbia River reservoirs. 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 the 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 discharge, 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. 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) (Figures 34 and 35). 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 34; Chapman and Jones 2010). Data from Age-0 indexing, combined with dam discharge data, suggest the relative density of Age-0 white sturgeon is positively correlated with 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 35; Chapman and Jones 2010; Parsley et al. 1993; Parsley and Beckman 1994).

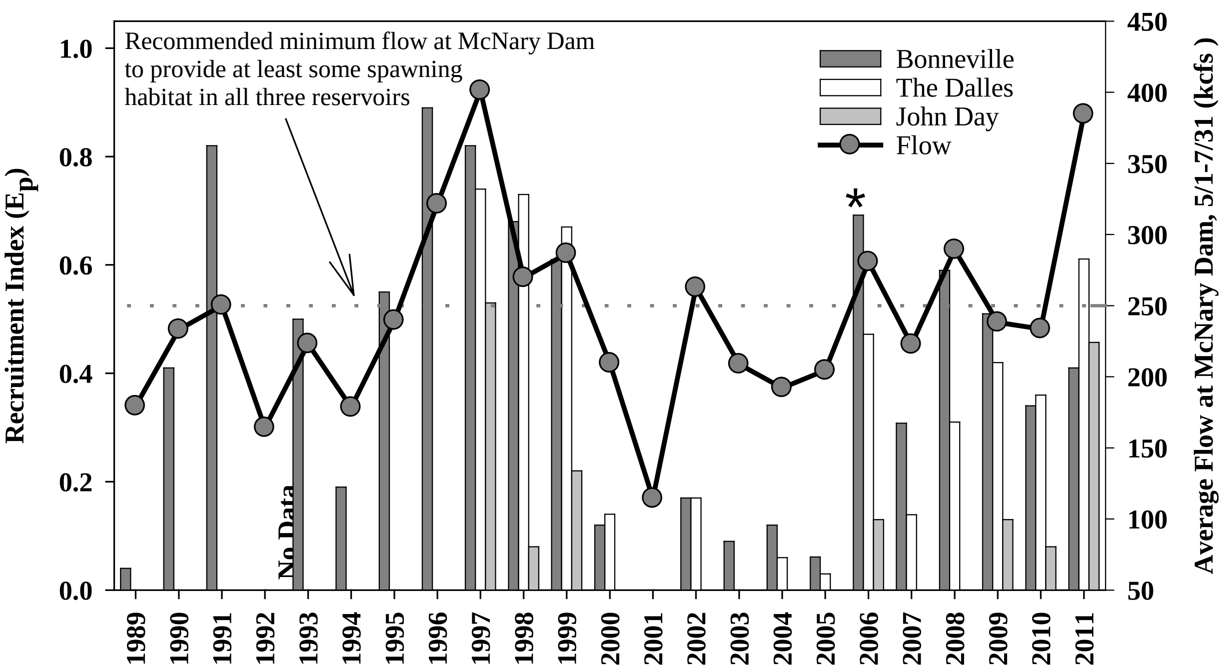


Figure 34. Recruitment index for white sturgeon in Bonneville, The Dalles, and John Day reservoirs, and average daily flow at McNary Dam (May-July). The dashed horizontal line indicates the recommended minimum flow to provide some spawning habitat in all three reservoirs.

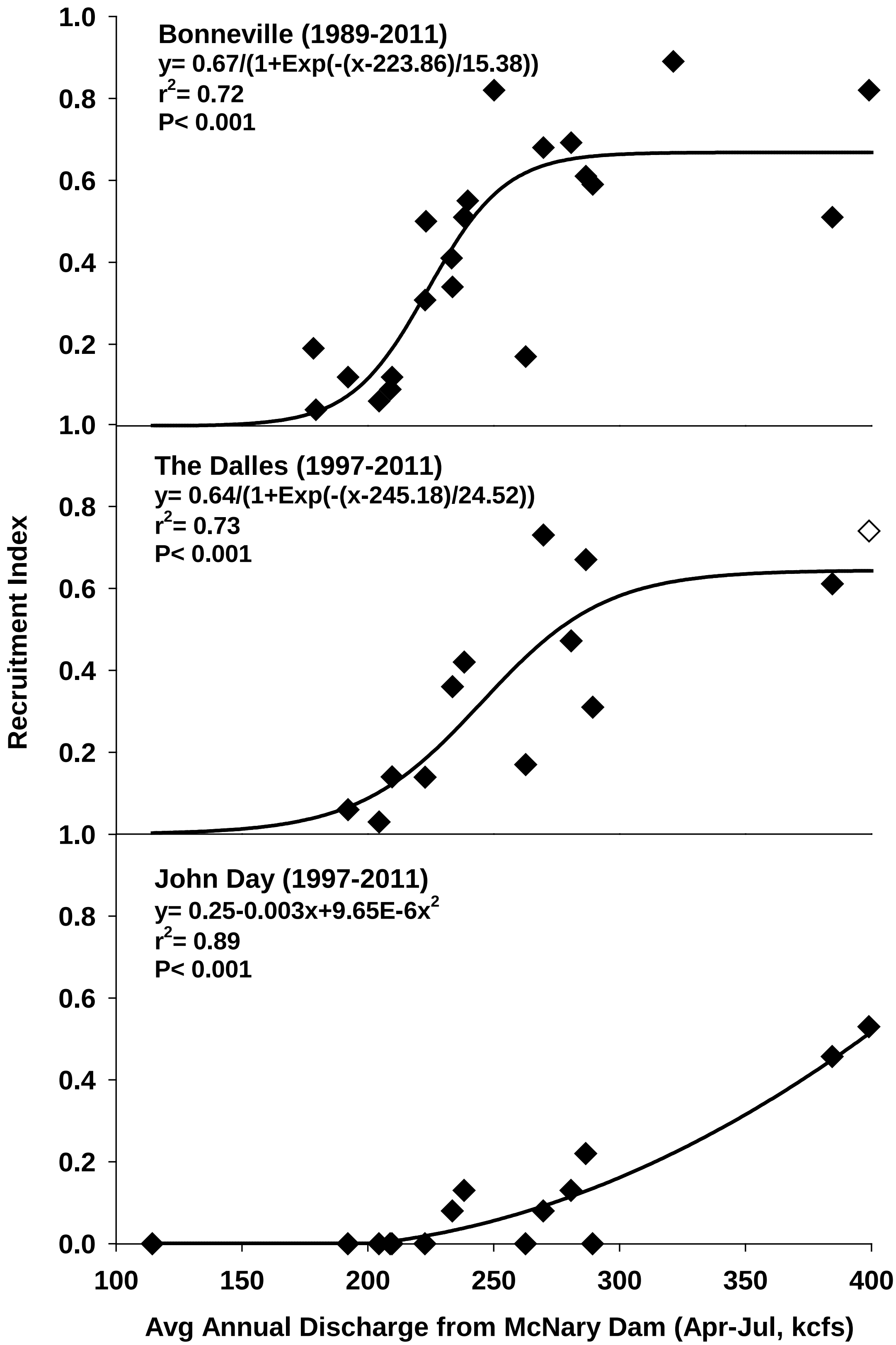


Figure 35. Relationship between annual recruitment index values and average discharge from McNary Dam (April-July) for Bonneville, The Dalles, and John Day reservoirs.

In addition to the alteration of the natural hydrograph, stream flow in the mainstem Columbia River can vary hourly and daily due to electrical load-following and power peaking operations (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).

Fisheries: White sturgeon in the Lower Mid-Columbia River are subject to a variety of fisheries. Removal of white sturgeon by fisheries (before they reach sexual maturity) 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. For the Zone 6 populations between Bonneville and McNary dams, where legal harvest is monitored and managed intensely, harvest is one of the few impacts that are easily quantifiable. Therefore, the impact of legal fisheries on lower Mid-Columbia River white sturgeon populations downstream of McNary Dam 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 in the Lower mid-Columbia River white sturgeon population in this reach.

For the lower Mid-Columbia River population above McNary Dam, the combination of infrequent population assessments, uncertainty in what constitutes sustainable harvest levels, coupled with a lack of fishery monitoring and corresponding regulations tuned to changing population status, increases the risk of exceeding sustainable harvest levels. Managers have chosen to impose greater fishery restrictions as a consequence of this uncertainty.

A similar situation exists for the white sturgeon populations within the lower Snake River Management Unit, with the same uncertainty in population status and a lack of information on sustainable harvest levels with no fishery monitoring other than the catch-record-card program. Managers are evaluating the need for additional fishery restrictions for these three populations in response to this uncertainty and evidence that these populations exhibit frequent recruitment failures and likely do not support existing harvest levels.

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 and the Washington Department of Fish and Wildlife. 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 limit white sturgeon spawning and recruitment. Peak spawning in the Lower Mid-Columbia River occurs at 55 to 59 °F (12.8-15.0^{o}C;

Parsley and Beckman 1994), though some may still occur at 64 to 66 °F (17.7-18.9^{o}C; McCabe and Tracy 1994). Optimum water temperatures for the development of white sturgeon eggs and larvae are between 52 to 63 °F (11.1-17.2^{o}C) with negative impacts to larval development at temperatures above 63 °F (17.2^{o}C; Wang et al. 1985).

Hydrosystem operations can cause unnatural and early increases in river water temperatures (Quinn and Adams 1996) to levels that can reduce the amount of suitable 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. In some areas of the Basin, particularly in upstream or headwater reaches, hydro operations and the heat-sink nature of storage reservoirs may delay season warming prior to spawning, and may effectively shorten the annual duration of suitable spawning temperatures (P. Anders Cramer Fish Sciences, personal communication, 2013).

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 web.

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. 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 and piscivory 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.

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. Mortality mainly results 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).

Plans, Objectives & Strategies

> ***Primary co-managers for white sturgeon in this reach:*** *Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, Bands of the Yakama Nation; Confederated Tribes of the Warm Springs Reservation of Oregon; Confederated Tribes of the Umatilla Indian Reservation; Nez Perce Tribe; Columbia River Inter-Tribal Fish Commission*

No overarching management plan currently exists for this management unit. However, a collaborative and comprehensive strategic plan for sturgeon conservation, restoration, and management, 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 is 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).

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, all attempts to date have failed to restore levels of natural recruitment adequate to support population persistence, sustainability, and where feasible 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. These 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 Dam, and concerns regarding 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 (2009-2013) of the Yakama Sturgeon Management Project (2008-455-00) addresses 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 provided critical input into the strategic and hatchery master planning process, helped determine the potential suitability of tribal hatchery facilities for sturgeon, and facilitated implementation of appropriate hatchery-related measures identified in the strategic and master planning process.

Needs & Uncertainties

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

- Factors affecting variability in the abundance and passage of white sturgeon in the lower Mid-Columbia River population segment (and elsewhere in the Basin).

- 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 in various areas of the Basin, including from Bonneville to Priest Rapids dams is currently unknown.
- Seasonal and diel habitat use by various life stages of white sturgeon remains unclear.
- Factors affecting variability in productivity - Annual growth, length-weight relationship, and relative weight of white sturgeon in Zone 6 reservoirs.
- Uncertainty regarding application of reservoir- or reach-specific genetic diversity, population differentiation, and gene flow information to guide specific management actions .
- 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 is needed on the loss of the historic prey base, and the nutritional value of current prey 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 and includes Priest Rapids, Wanapum, Rock Island, Rocky Reach, and Wells Dams (Figure 36).

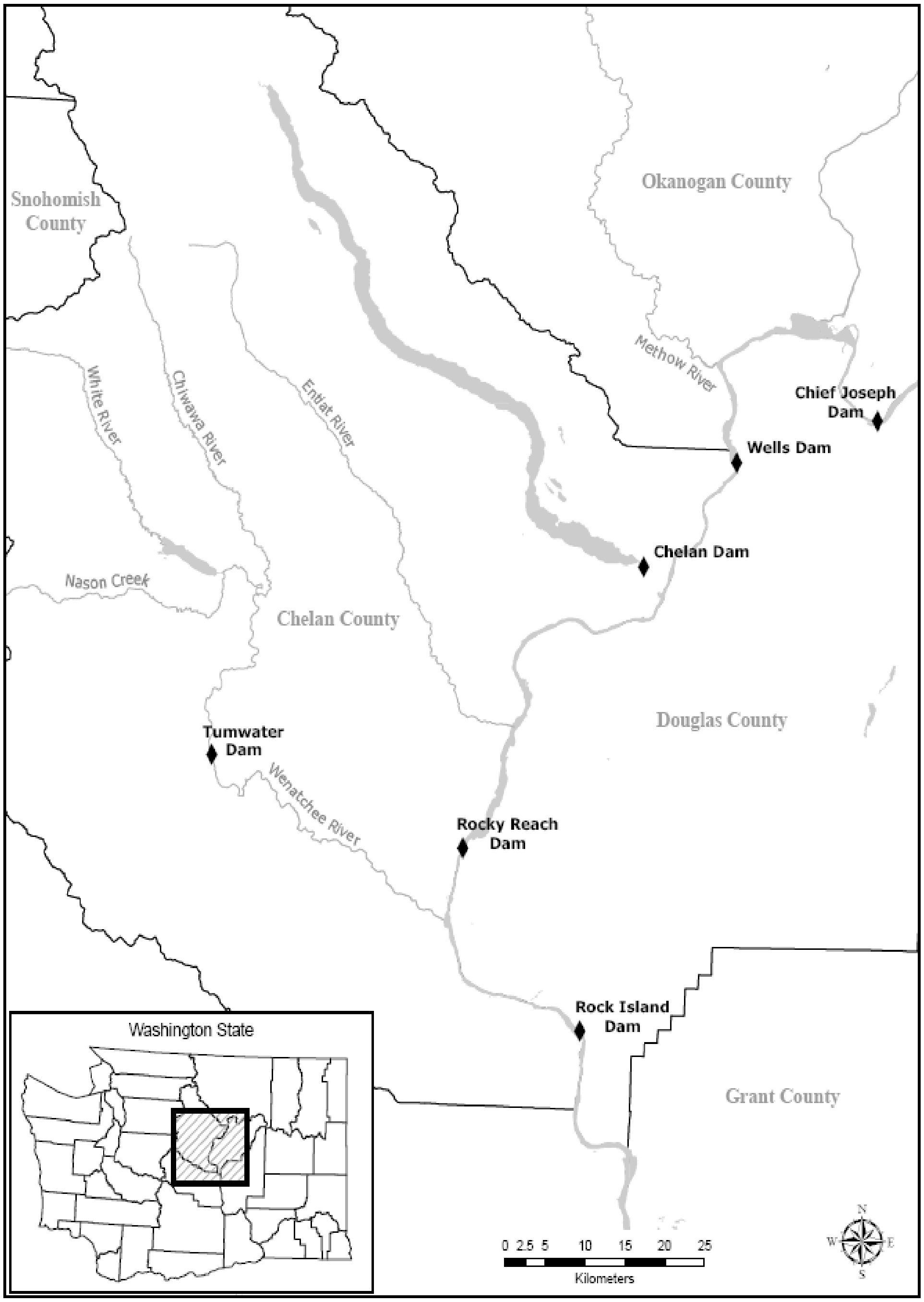


Figure 36. Map of the Upper Mid-Columbia management unit, Priest Rapids Dam to Grand Coulee Dam (NPCC 2004).

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. Abundance of these populations is believed to be declining or possibly stable at a low level because spawning and/or recruitment success is minimal to nonexistent.

Limiting Factors & Threats

Habitat Fragmentation

White sturgeon in the middle and upper Columbia River occupy human-controlled and impounded reservoirs between dams. The population dynamics and factors regulating production of white sturgeon in these areas are poorly understood. Sporadic or failing natural recruitment is characteristic of the impounded sturgeon populations. 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 appear to spawn in the tailrace areas of upstream dams on an annual basis. However, the juvenile or larval fish have a very low survival rate in each d reservoir, which leads to recruitment failure and 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.

In 2003, a substantial number of the 20,600 hatchery sturgeon released by CRITFC in Rock Island Reservoir were subsequently recaptured in Wanapum and Priest Rapids reservoirs, with some individuals moving downstream as far as The Dalles Reservoir. Hatchery-produced sturgeon were also stocked into Wanapum, Priest Rapids, and Rocky reach reservoirs and many were documented heading downstream (GCPUD). Although studies have demonstrated that conditions in the reservoirs are apparently suitable for juvenile growth and survival (Citation(s)?), the specific reason(s) for outmigration are unknown. Thus, some young sturgeon are either being entrained or actively migrating to downstream 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 after release. Conversely, many of the progeny from local-origin broodstock have remained in the reservoirs after being stocked and have survived at greater rates (J. Murauskas, CPUD). Furthermore, Chelan PUD's stocking efforts in Rocky Reach Reservoir have found nearly 100% of acoustic-tagged juveniles remained in the upper reaches of the reservoir and are surviving at nearly 100%. There is no evidence of "entrainment," or limited habitat, and data actually point to the contrary (J. Murauskas, CPUD). Based on the observed variation, many factors may affect post-stocking behavior and habit use.

Predation due to Changes in 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.

The detection of 58 PIT-tags from juvenile white sturgeon released in Wanapum Reservoir at a known bird colony in the Rock Island Dam forebay indicates that avian predation is a potentially significant factor affecting early survival of hatchery reared juvenile white sturgeon in some Wanapum Reservoir and potentially in other middle Columbia reservoirs (Golder 2013).

Plans, Objectives & Strategies

Primary co-managers for white sturgeon in this reach: *Washington Department of Fish and Wildlife; Bands of the Yakama Nation; Confederated Tribes of the Colville Reservation; Confederated Tribes of the Umatilla Indian Reservation. Key contributing parties include: Columbia River Inter-Tribal Fish Commission; and Chelan, Grant, and Douglas Public Utility Districts Columbia River Inter-Tribal Fish Commission*

OR: ***Other parties with sturgeon programs:*** *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 have 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 (GPUD 2008). 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:

- 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: 1) identify existing impediments to achieving the biological objectives, 2) sustain the populations until the existing impediments can be corrected, and 3) 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 (Chelan 2006). 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 received a new FERC license in 2012 and will have similar requirement to Grant and Chelan Counties. The Wells Hydroelectric Project White Sturgeon Management Plan (DCPUD 2008) 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.

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 other interested and affected parties.

Projects through Priest Rapids Project White Sturgeon Management Plan

A new GCPUD hatchery is still in the planning stage. Present stocking commitments for PR and RR are being met through collaborative broodstock collection program (Grant, Chelan, Yakima) with progeny for stocking in PR project area being raised at Yakima's Marion Drain facility and at the Columbia Basin Hatchery until release. Hatchery production measures include:

- Annual broodstock collections began 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.
- Evaluate natural production potential beginning in 2013.
- 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 and wild larvae (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 its 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 are currently being held at the Yakama Nation Marion Drain White Sturgeon Hatchery and the WDFW Columbia Basin Hatchery (GPUD's fish) and the WDFW Chelan Hatchery (CPUD's fish). Reduced stocking levels occurred in 2012 (500-1,000 fish range) due to the low number of brood stock collected in 2011. The 2013 brood stocking plans for Grant PUD and Chelan PUD are essentially the same as 2012, with hopes of increasing effort and collecting additional 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 initiating their hatchery supplementation program in 2013, with the first releases occurring in 2014. Douglas is implementing a dual strategy for the collection of white sturgeon offspring starting in the spring/summer of 2013. These two approaches will include the implementation of a wild larvae collection program and an adult brood collection programs. All offspring will be reared at the Wells Fish Hatchery.

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.
- More research of factors influencing natural recruitment in these river segments is needed.

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 primarily occupies in the riverine portion of the transboundary reach and the upper one-third of Lake Roosevelt (Figure 37).

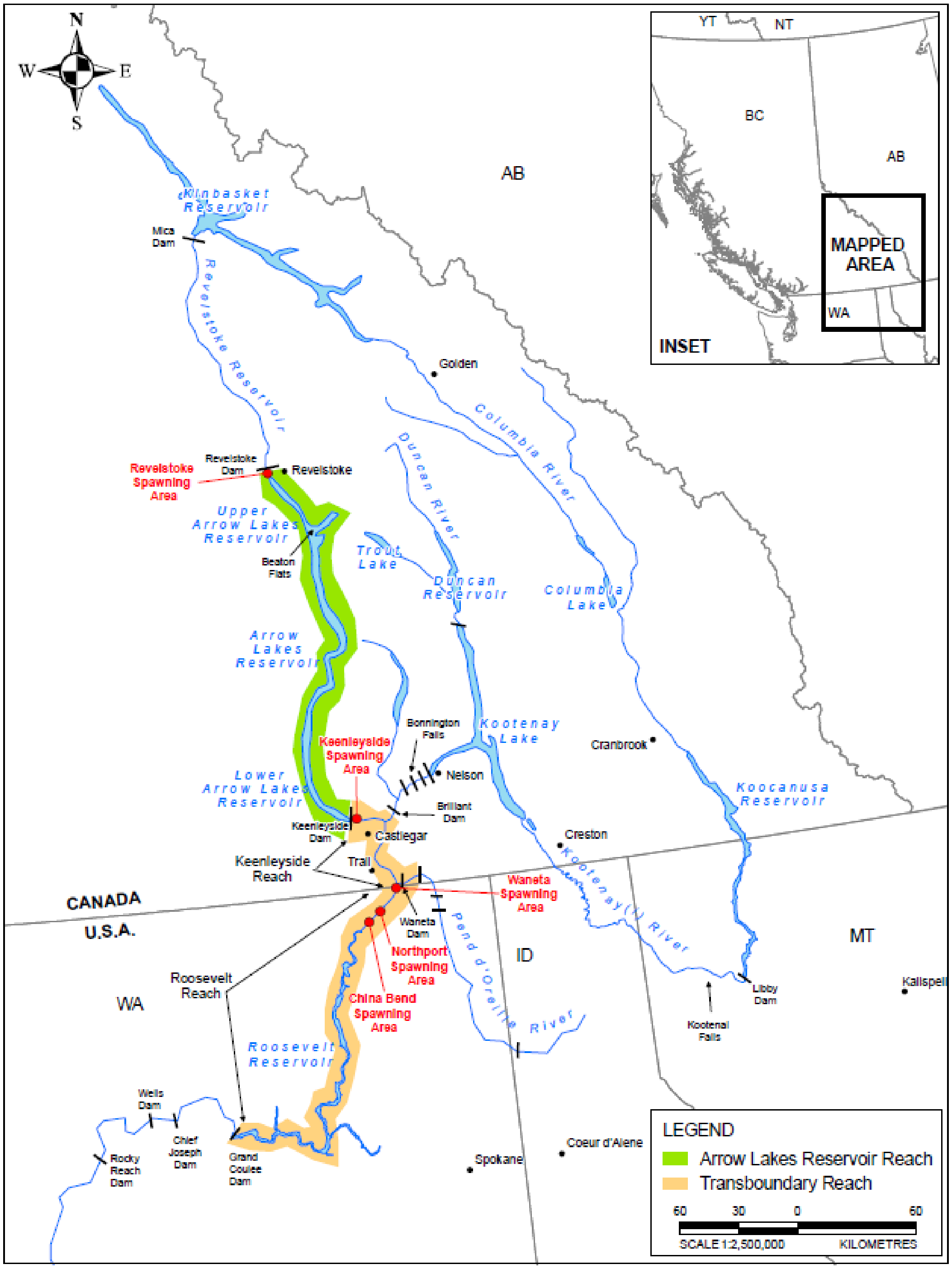


Figure 37. The Transboundary Upper Columbia River Management Unit.

Status

The decline of the Upper Columbia white sturgeon population began with recruitment failure in the 1960s and 1970s, which was not recognized until the early 1990s. A range of potentially limiting factors has been identified to explain ongoing recruitment failure in the Upper Columbia (Table 12). Because of very low early life stage survival and delayed maturation, the wild population now consists primarily of aging cohorts of mature fish that are gradually declining as fish die and are not being replaced at the same rate by wild produced progeny. The rate of decline after 2050 is expected to increase as most fish approach 100 years of age, which is considered their approximate maximum life span. Based on an annual mortality rate of 2.9%, recent projections suggest that the wild population will decline to below 500 fish within 50 years and to fewer than 50 fish by 2140 (Hildebrand and Parsley 2013). The Upper Columbia White Sturgeon Recovery Plan (UCWSRP) was developed in 2002 to identify and initiate many short-term measures aimed to stop the decline by supplementing the existing population through a conservation aquaculture program and by investigating and addressing the causes of recruitment failure.

Investigations over the last decade built on previous research. White sturgeon in the Canadian reach of the Columbia River between Keenleyside Dam and the international boundary have been intensively studied since 1990 (RL&L, 1994a, 1994b, 1995a, 1995b, 1996c, 1997a, 1998a, 1998b, 1998d, 1999a, 2000b; Golder 2002, 2003, 2005, 2006a, 2008, 2009a, 2009b, 2010, 2011c; Hildebrand et al 1999; BC Hydro unpubl. data). Over the past 20 years, as the current population has aged, size distribution in Canadian samples has steadily shifted from a population dominated by juvenile and sub-adult fish less than 100 cm in length, to one dominated by sub adult and adult fish greater than 100 cm in length. The studies show that sturgeon in this reach are concentrated throughout the year in several deep, low velocity habitats that represent high use areas for white sturgeon: the 7 km long section downstream from Keenleyside Dam, Kootenay eddy at the Columbia-Kootenay Rivers confluence, Fort Shepherd Eddy, and Waneta Eddy at the Columbia-Pend d'Oreille River confluence (Hildebrand et al. 1999).

Table 12. Critical areas and periods for white sturgeon life history stages in the transboundary reach of the upper Columbia River (adapted from Hildebrand and Birch 1996).

Life Requisite	Critical Period and Areas	Comments
Spawning	Period: June to late July Known areas: *HLK to Grand Coulee*: Northport, China Bend, Waneta Dam tailrace, and HLK tailrace. *Upstream of HLK dam*: Revelstoke Dam tailrace	Predation rates on eggs are unknown but selection of high velocity (typically > 1 m/s near bottom velocity) areas for spawning and egg incubation may result in similar pre- and post-regulation predation rates.
Incubation	PeriodJune to late July Areas: Northport, China Bend, Waneta Dam tailrace, and HLK tailrace	Eggs incubate for 5-10 days depending on water temperature. Rates of survival to hatch are unknown but may be influenced by water quality (clarity and contaminants) and substrate characteristics that protect embryos from physical damage and predation.
Yolk sac larvae	Period: June to late August Areas: Northport, China Bend, Waneta Dam tailrace, and HLK tailrace	Stage begins before hatch. Endogenous feeding larvae seek hiding places within interstitial spaces in substrates or exhibit a swim-up and downstream dispersal to suitable rearing habitats. Sampling and in-situ egg incubation experiments indicate some eggs hatch to this stage. Predation and energy expenditure required for hiding likely influence survival rates.
Feeding Larvae	Period: June to late August	Follows absorption of the yolk and shift to exogenous feeding. Feeding larvae actively move onto substrate surfaces to seek food. This may be the most critical period in the recruitment cycle, where predation, starvation, and other factors influence survival rates.
Young-of-ye ar	Period: August to December	Refers to fish that have their full fins and scutes and resemble adults in miniature. No wild spawned young-of-the-year have been captured in area. Many factors influence food abundance at this life stage. Increased predation associated with increased predator abundance, reduced flow volume and increased water clarity may have reduced survival.
Younger juveniles	Areas: Expected to be found in same habitats as older juveniles and adults	Represents age-1 to age-7 fish. Low survival at larval and YOY stages likely accounts for low abundance or wild younger juveniles. Main factors limiting use by this life-stage are habitat availability and suitability. Changes in biotic productivity of river may influence food availability and influence growth and survival.
Older juveniles	Period: All year Areas: Found in same habitats as adults	Ages 8 to 15; most fish > age-15. 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	Period: All year; greater use from May to October	Represents immature sub-adults (15 to 30 years old) and mature adults (generally older than age-30; population in

Life Requisite	Critical Period and Areas	Comments
Feeding	Known areas: *In B.C.*: HLK area, Kootenay, Fort Shepherd, and Waneta eddies. *In U.S.*: near Kettle Falls, China Bend, and Dead Man's Eddy	transboundary reach composed mainly of fish older than age-30; limited sampling in U.S. indicates similar size-class (and presumably age-class) composition. Highest use in all seasons is for areas with depths over 15 m; food abundance/composition has changed due to dam operations and exotic species introductions.
Overwintering	Period: November to March Known areas: *in B.C.*: HLK area, Kootenay, Ft Shepherd, and Waneta. *In U.S.*: China Creek and primarily near Marcus and Seven Bays area	In winter, fish tend to be found in deeper water (>20 m depth) than during other times of the year. Since the availability of deep-water habitats in riverine reaches 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 by increasing metabolic demands.
Staging Pre-spawners	Period: November to late May Known areas: Ft. Shepherd eddy, Waneta eddy, and the HLK area; use of the Kootenay Eddy for staging undocumented	Represents areas selected by pre-spawning females (and possibly pre-spawning males) with suitable low velocity holding areas near spawning areas; higher use of Ft. Shepherd Eddy may reflect depths >50 m at location; flow fluctuations that increase velocities in staging areas and temperature increases during winter may affect spawning intensity.

Intensive annual studies of white sturgeon in the U.S. reach of the Upper Columbia from Lake Roosevelt to the international boundary began in 1998. These studies show distribution of wild sturgeon over 100 cm FL throughout the area upstream from Gifford in Lake Roosevelt (DeVore et al. 2000; Howell and McLellan 2007a, 2007b, 2008, 2011, in prep). Juvenile sturgeon from hatchery releases were concentrated in the river-reservoir transition zone from Marcus upstream (Howell and McLellan 2011; Howell and McLellan in prep). High use areas included the Little Dalles and Marcus Flats, with most adults found in the river-reservoir interface area and the mainstem Columbia River upstream to the international boundary. Older sturgeon were more widely distributed in the summer than during the early spring (i.e. at the tail-end of overwintering) when fish were most heavily concentrated in the area between the Colville River mouth upstream through the Marcus Flats area (Hildebrand and Parsley 2013).

Setline and gill net sampling in the reach have captured very few wild sub-yearling or older juvenile white sturgeon (Lee and Underwood 2002; Lee and Pavlik 2003; Golder 2009a; Howell and McLellan 2011; Howell and McLellan in review). Between 2000 and 2011, juvenile indexing surveys captured nine wild juveniles (i.e., untagged/unmarked fish <150 cm TL) in the reach between the international boundary and Keenleyside Dam (Golder 2009a; BC Hydro in prep) and 37 wild juveniles (<100 cm FL) in the U.S. portion of the reach that contains Lake Roosevelt (WDFW, unpublished data). In 1998, WDFW captured two wild juvenile (<100 cm FL) sturgeon.

Studies conducted in the transboundary reach show that as the white sturgeon population in the reach has aged, size and maturity distribution has steadily shifted from a wild population dominated by juvenile and subadult fish less than 150 cm FL to one dominated by adult fish greater than 150 cm FL (Hildebrand et al. 1999; Irvine et al. 2007; Howell and McLellan 2008). Howell and McLellan (2007b) estimated that of the 3,100 wild white sturgeon in the entire transboundary reach approximately 79% were adult fish over 165 cm FL.

Collectively, studies confirm that natural recruitment of white sturgeon in the transboundary reach is rare, consistent with previously reported recruitment collapse. In upcoming decades, fewer adult fish will remain to take advantage of suitable natural recruitment conditions (if they occur) and it will become increasingly difficult to capture the broodstock needed to sustain an artificial supplementation program. Continued uncertainty about the nature of the recruitment problem(s) will likely delay identification of potential solutions to restore natural recruitment. To date only the longevity of this species and complete fishery closures have forestalled their extirpation. Effective, immediate intervention is needed to support their recovery.

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). Construction of Keenleyside Dam in 1968 further isolated white sturgeon in the reach by cutting off access to historical spawning, rearing and feeding habitats in the upper basin. The dams replaced much of the former highly diverse and productive riverine ecosystem in the reach with a homogenous, oligotrophic reservoir that provides marginal habitat. The fragmented reach may no longer provide the full spectrum of habitats necessary for resident sturgeon to complete their life cycle.

Considerable information on the extent of white sturgeon movements and mixing in the transboundary reach has been collected since 1990 (Golder 2006a, 2009a; Howell and McLellan 2007b; Irvine et al. 2007; Van Poorten and McAdam 2010; Clarke et al. 2011; Nelson and McAdam 2012; Howell and McLellan in prep.). These data indicate that white sturgeon primarily reside in the area extending from the upper third of Lake Roosevelt to Keenleyside Dam. Most fish tend to remain in relatively localized areas for extended periods but some move frequently among areas within the river system for spawning, feeding, or overwintering. In general, sturgeon in the transboundary reach ranged most widely during the period May-October with few long distance movements observed from November-April (Howell and McLellan 2011; Golder 2006a, 2009a).

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). Unregulated spring runoff peaked during June and July in the Upper Columbia River, often exceeding 4,500 cms (160,000 cfs). Current peak flow averages about 1,700 cms (60,000cfs).

The magnitude of the change in the river environment from the pre- to post-regulation flow regime and the known effects of flow on sturgeon recruitment strongly suggest that flow changes are a primary cause of recruitment failure. 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. High flows help disperse newly hatched free embryos to suitable rearing habitat. Periodic floods flush fine sediment from river bed cobbles and prevent armoring, while the increased turbidity provides juvenile sturgeon cover from potential predators while they move downstream.

A noticeable recruitment pulse in 1997 during higher flows illustrates the benefits of high flows in the Upper Columbia River recovery area. During the recruitment pulse, flows in the transboundary reach were near average pre-regulation flows and considerably above post-regulation average flows (Figure 38). Water temperatures at the international boundary reached 14º C (i.e., the optimal spawning temperature) in mid-late June 1997. First feeding larvae would likely have been abundant by mid-July, which coincided with a large secondary peak in discharge that may have aided larval survival through more effective dispersal to nursery habitats further downstream in the Roosevelt reach or by reductions in predation due to greater flow volumes and turbidity. However, it is important to note that high flow events have not always led to detectable recruitment, which further emphasizes that changes coinciding with high flows can lead to a complex set of secondary effects (Hildebrand and Parsley 2013)(Figure 38).

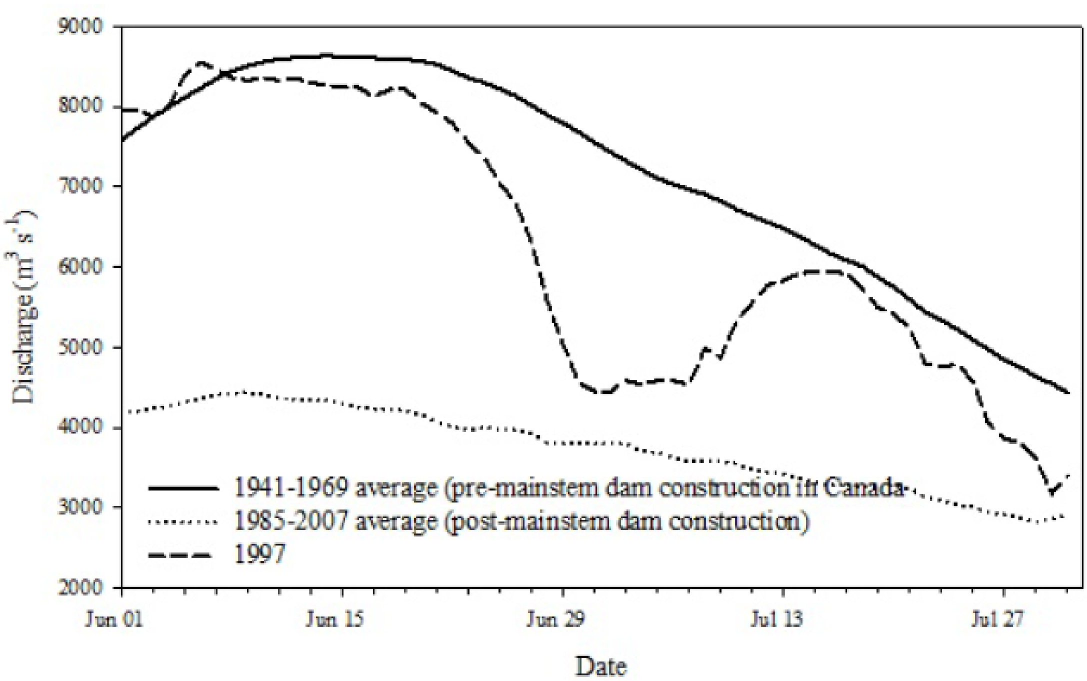


Figure 38. Comparisons of Columbia River discharge at the Canada-U.S. boundary pre- and post-mainstem dam construction in Canada, and in 1997 - a year when a detectable pulse of White Sturgeon recruitment occurred (Hildebrand and Parsley 2013, from RESCAT 2012).

In the past 11 years, there have been five years when flows have exceeded 5,660 cms (200,000 cfs) at the international boundary. The UCWSRI Technical Working Group has selected this flow level as a reasonably attainable target flow that is within flood control considerations and may help stimulate natural sturgeon recruitment (Table 13). Flows in 2011 and 2012 were exceptionally high and approached the pre-regulated average flow at the international boundary. The 2011 and 2112 flow volumes also stayed substantially higher for a greater length of time than in 1997, when flows in the transboundary reach were near average pre-regulation flows and a detectable recruitment pulse occurred (Hildebrand and Parsley 2013).

Table 13. Summary of the last 11 years (2001 – 2012) where the Columbia River mean daily flow at the Canada/U.S. boundary exceeded 5,660 cms. Duration is presented as the total number of consecutive days that 5,660 cms was exceeded in each of the five years (source: Hildebrand and Parsley 2013).

Year	Maximum (cms)	Duration (Days) >5,660 cms
2002	6,524	9
2006	6,435	11
2008	6,134	17
2011	7,560	50
2012	7,906	55

Hydro system operations also can cause weekly and daily flow fluctuations for power load. For example, in some years peaking operations from Waneta Dam occur during the latter portion of the white sturgeon spawning period and can affect flow conditions downstream in the Waneta spawning area at the Columbia-Pend d'Oreille Rivers confluence. Spawning has occurred during periods of peaking at Waneta, although egg deposition primarily occurs in areas of the confluence where flow velocities are determined by Columbia River flows (ASL et al. 2007; Golder 2011c). Nevertheless, the effects of such peaking operations on white sturgeon remain unclear. Although spawning in this area is not producing significant numbers of juvenile sturgeon, spawning in other areas of the Upper Columbia River that are not influenced directly by daily hydro-peaking operations are also failing to produce substantive recruitment.

Water Quality

Temperature

Significant changes in water temperature accompanied construction and operation of the dams and reservoirs. Downstream of Keenleyside Dam, average fall and winter temperatures are generally similar to pre-impoundment levels but temperatures from May through September are 2-3º C warmer than occurred historically. Recent observations suggest that winter water temperatures since 1990 are warmer and cold winter periods are briefer downstream of Keenleyside Dam (Golder, unpublished data). Pend d'Oreille River temperatures currently rise faster than in the Columbia River during the spawning season and get much warmer (e.g., up to 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.

The effects of these altered temperature patterns on white sturgeon productivity in the Upper Columbia are poorly understood. 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; Van Poorten and McAdam 2010). Still, changes in water temperature due to river regulation are considered a less likely cause of recruitment failure than flow effects (Hildebrand and Parsley 2013). Pre-versus post-regulation water temperature patterns in the transboundary reach have not exhibited the same magnitude of change as flow. Water temperatures vary year to year and suitable temperature conditions to support recruitment should have been present in some years since recruitment failure occurred in the early 1970s.

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.

The UCWSRI recently completed a summary of contaminants in the Upper Columbia River and their potential impact to white sturgeon health (AMEC 2012). Research to date does not indicate that any known contaminants in the Upper Columbia River recovery area have directly or indirectly caused white sturgeon recruitment failure (Hildebrand and Parsley 2013; see also McAdam 2012). Contaminant inputs into the Upper Columbia River are presently regulated by federal, provincial, and state agencies and adherence to these regulatory guidelines is assumed sufficient to protect existing white sturgeon.

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 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.

Recent studies in the transboundary reach examined the availability of food for larval sturgeon at the onset of exogenous feeding, with the premise that lack of suitable food at critical times could result in decreased larval or early juvenile survival. Capture of larvae downstream from the Northport and China Bend spawning areas and examination of the diet by WDFW has verified that larvae are feeding (Howell and McLellan in review). Further, studies initiated in 2012 between the international border and Keenleyside Dam sampled the river for available food items and examined the diet of age-1+ juveniles. Preliminary study findings indicated that a high proportion of the white sturgeon had full stomachs that contained a wide variety of food items (BC Hydro, unpublished data). These studies indicate that, while nutrient transport and productivity in the Upper Columbia River have undoubtedly been impacted by river regulation, the changes are not a primary reason for white sturgeon recruitment failure in the transboundary reach. Documented feeding by larval stages, reasonable growth rates of juveniles and adults, and the apparent availability of suitable food resources for these life stages support this conclusion (Hildebrand and Parsley 2013).

Water Clarity

Construction of upstream and tributary reservoirs created large settling basins that reduce downstream sediment transport and river turbidity in the transboundary reach. The increased water clarity may have significant implications for sturgeon. For instance, the reduction in cover associated with turbidity leaves young sturgeon more vulnerable to potential predators, especially during the larval dispersal and first few months of life.

Habitat Diversity, Quality and Quantity

The former riverine habitat structure in the reach has been substantially altered by impoundment, channel modification, flood control, and flow regulation. Substantial diversity was lost because of impoundment. The mainstem reservoirs flooded large areas of former channel. Lake Roosevelt now covers over 240 km of formerly diverse riverine habitat. Further changes in river geomorphology occurred due to flood control and flow regulation. 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). They also reduce availability of complex habitats that 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. The loss of habitat for white sturgeon survival through early life stages may have particularly affected the population.

Increased Predation due to Changes in Fish Species Composition

The pre-development fish community in the Upper Columbia River included anadromous salmonids and a resident fish community dominated by mountain whitefish, rainbow trout, bull trout and burbot. Substantial changes in fish species composition accompanied dam development and introduction of exotic species 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.

Today, the fish community of the mainstem Columbia River between Keenleyside Dam and Lake Roosevelt is dominated by mountain whitefish, rainbow trout, northern pikeminnow, and suckers. Kokanee are also common, with most likely entrained from Arrow Lake but a few also originating in Lake Roosevelt. Walleye, first introduced into the Upper Columbia River in the 1960s, have become an abundant sport fish. Abundance of smallmouth bass, largemouth bass, yellow perch, black crappie, and pumpkinseed has also increased steadily in the reach. In Lake Roosevelt, introduced species such as walleye and smallmouth bass, as well as kokanee salmon dominate the current fish community.

Early life stages of white sturgeon are particularly vulnerable to predation by non-native and native fish. Potential predators dominate many areas in upper Lake Roosevelt during the time when early life stages of sturgeon are present. At the same time, larval and juvenile sturgeon are more vulnerable to predators due to the reduction in water turbidity and suitable refuge habitat that followed construction of the large upstream reservoirs.

Exploitation and Incidental Catch

White sturgeon are vulnerable to overfishing because of their delayed age of maturation (15 years or greater) and longevity (up to 100 years) (Beamesderfer and Farr 1997). Unproductive sturgeon populations, including the Upper Columbia populations, cannot sustain any level of harvest and productive sturgeon populations can only sustain very low (5% to 10%) exploitation rates (Rieman and Beamesderfer 1990).

Since 1996, fishing for white sturgeon has been prohibited in both Canadian and U.S. portions of the Upper Columbia River area. Incidental catch is low for adult white sturgeon and high for juveniles in the transboundary reach. Currently, there is no data available to determine the effect of incidental angling catch on survival of either adult or juvenile white sturgeon.

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, Okanagan Nation Alliance, Spokane Tribe, Canada Dept. of Fisheries and Oceans*

Upper Columbia White Sturgeon Recovery Plan

The Upper Columbia White Salmon Recovery Initiative (UCWSRI) developed the original Upper Columbia White Sturgeon Recovery Plan in 2002 and completed the first plan update in 2012 (Hildebrand and Parsley 2013). The recovery plan is the product of a cooperative effort by Canadian and U.S. governmental aboriginal, industrial and environmental organizations, stewardship groups, and citizens. A recovery team included technical representatives from federal, provincial, and state resource management agencies, and Canadian and U.S. tribes. Plan development involved representatives from 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.nwcouncil.org/media/6836165/uppercolsturgeonplandec2012.pdf.

The recovery plan is a "living document" and is adaptive in nature. It describes objectives, targets, strategies, measures, and schedules 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.

The 2002 recovery plan focused on short-term measures to supplement the existing white sturgeon population, assess population status and investigate potential causes of recruitment failure. Implementation of these recovery measures arrested the further decline of the population, and made substantial gains towards understanding population status and identifying limitations to restoration of natural reproduction.

The 2012 revision of the Upper Columbia White Sturgeon Recovery Plan builds on the achievements of the original plan. It updates objectives, targets, strategies, and measures for arresting the decline of white sturgeon in the Upper Columbia, promoting the persistence and viability of naturally reproducing populations, and restoring opportunities for beneficial use if feasible.

<u>Recovery Objectives</u>

The primary objectives of the 2012 recovery plan are to: 1) continue to monitor the status and trends of populations within the recovery areas, 2) continue supplementation to rebuild abundance and maintain genetic diversity, and 3) identify and address factors limiting natural recruitment.

Recovery efforts will focus on three areas within the historical geographic range that continue to provide suitable white sturgeon habitat. Two of these areas lie within the Transboundary Upper Columbia management unit: the upper transboundary reach (Keenleyside Dam to the international boundary) and the lower transboundary reach (international boundary to Grand Coulee Dam). The other area is Arrow Lakes Reservoir (Revelstoke Dam to Keenleyside Dam). Recovery planning efforts will continually evaluate this approach as numbers of fish present in the entire transboundary reach increase through recovery efforts on both side of the international boundary.

Recovery efforts will also consider establishing one or more additional recovery areas or "fail safe" populations in the Arrow Lakes Reservoir reach and/or the Kinbasket reach, which includes Columbia Lake, the unimpounded portion of the Upper Columbia River, and Kinbasket Reservoir formed by Mica Dam. 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. Fail-safe populations may be established in areas of suitable habitat that either no longer contain sturgeon or that presently support a non-sustainable sturgeon population segment. This would involve a release of hatchery fish in an area separate from existing recovery areas, which can be used as a future source of white sturgeon to support population abundance and diversity in other recovery areas. Genetic and demographic risks to existing wild populations can be minimized by establishing the failsafe population where the potential for straying can be controlled and monitored.

Further, the updated 2012 recovery plan involves an adaptive management approach that involves the continued modification of the program based on results of research on limiting factors and monitoring of stock status and its response to recovery actions. Currently, long-term recovery planning is hampered by a lack of understanding of key limiting factors. Laboratory studies will continue to provide information necessary to evaluate field-scale recovery actions. Field research and monitoring will continue to provide information on ecological impediments to recovery.

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.

Recovery Targets

The 2012 Upper Columbia White Sturgeon Recovery Plan establishes recovery targets by which progress toward recovery will be measured (Hildebrand and Parsley 2013). A minimum of 25+ years will be required to approach many of these recovery targets because of the long life span and generation time of sturgeon. Targets identified in the plan are based on population viability guidelines identified in the scientific literature and are similar to those adopted in the draft Canadian National Recovery Strategy for White Sturgeon and in recovery plans for other vulnerable sturgeon populations. Recovery targets for Upper Columbia River White Sturgeon include:

1. *Minimum interim adult population sizes of 2,000 adults in the upper transboundary reach (Canada) and 5,000 adults in the lower transboundary reach (U.S.)*

   Periodic population assessments will inform progress on meeting and /or adjusting this target in each recovery area. The target of 2,000 adults in the upper transboundary reach approximates the estimated historical adult population estimate and on this basis, is set as the interim target. The Lake Roosevelt co-managers have identified a long-term objective of achieving an abundance of 5,000 adults for the lower transboundary reach with adequate rates of natural recruitment to maintain the adult abundance (LRMT 2009). These abundance numbers are interim targets pending studies of habitat carrying capacity in designated recovery areas and may change based on capacity assessments. A target for the Arrow Lakes Reservoir reach has not presently been established.

2. *Naturally produced recruitment and juvenile population sizes sufficient to support desired adult population sizes in at least two of the three potential recovery areas identified above.*

   Research on survival limitations may allow improvements to habitat that will increase natural spawning survival and production. Supplementation will continue to build juvenile abundance. Population monitoring will provide information on natural production and juvenile abundance. Multiple recovery areas provide the spatial diversity necessary to protect the species from local impacts.

3. *Stable size and age distributions in each population.*

   Population monitoring will provide information on size and age distribution within recovery areas. Stable population numbers are required to demonstrate the effectiveness of long-term recovery actions. Stable size and age distributions reflect the longevity and normal population structure of sturgeon as well as providing the population resilience needed to sustain these fish over the long term.

4. *Genetic diversity (including rare allele frequencies) is preserved and is similar to that measured during the late 2000s.*

   Population monitoring and supplementation will provide information on efforts to maintain current levels of diversity (Drauch Schreier et al. 2011). Restoration of natural spawning and production will alleviate the need for supplementation. This will ensure that sufficient variability is preserved to allow sturgeon to use the available array of environments, protect against short-term spatial and temporal changes in the environment, and provide the raw material for surviving long-term environmental changes (McElhany et al. 2000).

5. *Abundance and natural production rates are sufficient to support beneficial uses including subsistence harvests by First Nations and Native American Indians and recreational fishery uses.*

   Population monitoring, supplementation, and reductions in limitations to natural production result in meeting recovery goals in U.S. and Canadian recovery areas. Natural reproduction rates sufficient to provide harvest or withstand other fishery impacts recognize a desire to restore historical fishing opportunities. Reproduction rates that provide a sustainable harvestable surplus also provide an additional safety factor from long-term risks to population viability.

The recovery plan does not identify specific ecosystem function targets or benchmarks, but recognizes that efforts to restore sturgeon populations through natural production are also likely to result from restoration of ecosystem function that in turn will benefit many other components of the native aquatic community.

<u>Recovery Strategies</u>

The recovery plan identifies the following strategies to achieve Upper Columbia white sturgeon recovery goals, objectives, and targets (Hildebrand and Parsley 2013).

1. *Control direct sources of adult and juvenile mortality.*
   Fishing for sturgeon in the U.S. and Canadian waters of the Upper Columbia River is currently prohibited and must remain so for the foreseeable future.

2. *Rebuild abundance through hatchery supplementation.*

Hatchery supplementation will continue into the foreseeable future to rebuild juvenile abundance while preserving the remaining population diversity. Hatchery methods, risks, and benefits require consistent and careful review at regular intervals throughout the recovery process to maintain genetic diversity and reduce selective pressures that may promote survival in a hatchery but not in the wild. Hatchery operations should strive to promote conditions that support riverine phenotypic expression by juveniles. Hatchery intervention is currently envisioned as a medium-term (5-10-year) strategy to be reevaluated once hatchery fish begin to reach maturity. The aggressive hatchery measures presently in place have successfully replaced 11 year-classes juveniles that would not have been produced by the existing population of aging, wild mature fish. Hatchery fish also serve as test subjects in the wild or the laboratory, subject to applicable permitting provisions, to experimentally investigate natural recruitment limitations, mortality factors, critical habitats, and feeding.

3. *Restore natural recruitment.*
   Restoration of natural recruitment will likely require implementation of habitat restoration actions developed from an understanding of relations between white sturgeon survival and habitat as defined by river flow, local hydraulics, riverbed substrates, water temperature, and water quality. Restoration of natural recruitment is required to achieve long-term recovery objectives. Necessary measures might involve modifications to the annual hydrograph in the Columbia and Pend d'Oreille Rivers or improvement or enhancement of important habitats (e.g., spawning or rearing areas). Actions also include continued population assessment, monitoring and research.

Programs, Projects, Actions & Schedules

Canadian Species at Risk Act and Recovery Strategy for White Sturgeon in Canada

The Canadian Species at Risk Act (SARA) prohibits harm to white sturgeon through general prohibitions that include killing, harming, harassing, capturing, taking, possessing, collecting, buying, selling or trading an individual; destroying any part of the species' critical habitat. DFO may issue permits to allow certain activities to occur that would otherwise be prohibited. Researchers wishing to conduct scientific research or conservation activities that affect white sturgeon, or persons undertaking activities that incidentally affect sturgeon, may be subject to SARA permitting provisions. Permits can be issued only for activities that meet certain pre-conditions, including that the activity does not jeopardize survival or recovery of the species. More information about SARA permitting can be found at http://www.dfo-mpo.gc.ca/species-especes/permits-permis/permits-eng.htm.

Upper Columbia white sturgeon are listed as Endangered under the Canadian SARA's List of Wildlife Species at Risk. Fisheries and Oceans Canada (DFO), the Canadian federal department responsible for white sturgeon recovery, worked together with the Province of British Columbia, First Nations, and other partners to draft a national recovery strategy for white sturgeon in Canada. A draft recovery strategy was released for public consultation in 2009 and is currently being finalized by DFO. The final document will provide recovery guidance for Upper

Columbia white sturgeon and three other listed white sturgeon populations within Canada. The recovery strategy will establish population and distribution objectives, identify critical habitat, and outline approaches to recovery. Following finalization of the recovery strategy, DFO will work with partners to develop a SARA action plan for the species. The action plan will include measures to protect critical habitat and monitor species recovery.

Upper Columbia White Sturgeon Recovery Initiative

The Upper Columbia White Sturgeon Recovery Plan, originally 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 UCWSRI completed its first revision of the original recovery plan in 2012. The revised plan reflects achievements over the last decades (Hildebrand and Parsley 2013).

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; promoting 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. The recovery plan embraces an adaptive management approach that involves the continued modification of the program based on results of research on limiting factors and monitoring of stock status and its response to recovery actions.

Existing Programs and Projects

Studies of white sturgeon in the Canadian reach of the Upper Columbia River began in the mid-1990s but few white sturgeon inventory and research efforts were conducted in the U.S. reach until formation of the UCWSRI, when the activities increased substantially. Current research includes:

- Broodstock collection and tagging activities
- Transboundary reach juvenile monitoring
- 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

Because of these activities, substantial progress has been made towards identifying limitations to restoration of natural reproduction of Upper Columbia white sturgeon. Knowledge gaps still exist, however, and population monitoring remains an ongoing component of the white sturgeon recovery efforts.

The UCWSRI also implemented the Upper Columbia sturgeon hatchery program in 2001. The program has focused on preserving wild genetic variability, rebuilding natural age class structure, and preventing extinction until natural recruitment can be restored. This goal has essentially been achieved. The history of the conservation aquaculture programs developed for white sturgeon recovery in the Upper Columbia River is summarized below.

The UCWSRI initiated a pilot hatchery program for upper Columbia white sturgeon in 2000 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.

Since 2002, the UCWSRI has implemented a suite of research, monitoring and evaluation, production, and outreach activities aimed to stop the decline of white sturgeon in the transboundary reach. The UCWSRI is now refining these activities based upon direction in its 2012 revised plan to further promote the persistence and viability of naturally reproducing populations.

As of January 2011, approximately 160,000 juvenile white sturgeon and 1.5 million larval white sturgeon having been released into the Upper Columbia River recovery area through the program. These fish were the progeny of broodstock captured in the transboundary reach and transported to various hatchery facilities in British Columbia and Washington State where they were spawned, fertilized, eggs hatched, and raised for release as larvae or older juveniles. From 2002 to 2011, 122,555 juveniles have been released in the transboundary reach (93,524 between the international boundary and Keenleyside Dam and 29,031 between Grand Coulee and the international boundary). Based on best available estimates of juvenile survival rates, an estimated 24,124 hatchery juveniles were present in the transboundary reach as of January 2012 (Table 14). Monitoring studies have indicated these fish are growing normally and to date, do not show any signs of density related changes in growth or survival rates (BC Hydro, unpublished data; Hildebrand and Parsley 2013).

In addition, since 2011 the U.S. program has collected wild larvae in the Roosevelt reach, raised them in a hatchery setting, and released them back into the river as juveniles (see Lake Roosevelt Sturgeon Recovery Project). The feasibility of a wild larval collection program in the Canadian section of the transboundary reach and rearing of these larvae in facilities adjacent to the Columbia River is also being investigated by the UCWSRI.

Table 14. Estimated number of white sturgeon hatchery juveniles released and surviving in the transboundary reach as of January 2012 (Hildebrand and Parsley 2013).

Year class	2001	2001	2003	2004	2005	2006	2007	2008	2009	2010	All Years
Number Released	8,671	11,803	11,576	16,503	20,218	15,587	14,298	7,678	7,820	8,401	122,105
Estimated Number Surviving	1,337	1,876	1,897	2,788	3,521	2,798	2,646	1,495	1,696	2,070	22,124

<u>Further Programs, Actions and Schedules</u>

The UCWSRI's 2012 Upper Columbia White Sturgeon Recovery Plan proposes a number of measures under each recovery strategies that aim to achieve the goals, objectives and targets for recovery of Upper Columbia white sturgeon. Specific recovery measures are identified for fishery regulations, entrainment, hatchery production, water management, water quality, contaminants, habitat diversity, population connectivity, system productivity, assessment, monitoring, research, information, education, planning, coordination, and implementation.

Timeframes for each measure reflect short (0-5 year), medium (5-10 year), and long (10- 50 year) term commitments for implementation of measures and expectations of results. Actual implementation schedules will be contingent upon the resources available for plan implementation.

- *Measures to control direct sources of adult and juvenile mortality* — *Schedule*
  1. Continue to prohibit fishing for and retention of sturgeon. — Short - long term
  2. Continue to limit incidental impacts and illegal harvest of sturgeon. — Short - long term
  3. Continue to monitor occurrence of sturgeon mortalities. — Short - long term
  4. Continue to monitor mortality or harm through the operations of dams and hydroelectric facilities. Implement operational mitigation measures if necessary. — Short - long term

- *Measures to rebuild abundance through hatchery supplementation* — *Schedule*
  1. Pursue a fish culture strategy to conserve existing population diversity. — Short - med term
  2. Use hatchery-reared offspring of wild adults to assist in research. — Short - med term
  3. Establish failsafe adult population(s) where feasible and acceptable. — Med - long term
  4. Use cryopreservation techniques to preserve white sturgeon sperm. — Short term

- *Measures to restore natural recruitment* — *Schedule*
  1. Water Management
     a. Monitor and evaluate the effects of flow on natural recruitment using opportunistic flow years that minimize — Short - long term

impacts on other uses of basin waters.	
b. Implement flow requirements to promote natural spawning, incubation, rearing, recruitment, survival.	Short - long term
c. Continue to assess impacts of dam discharge and reservoir operations on early life stages.	Short - long term
d. Future Treaties, agreements, or water licenses should promote sturgeon recovery.	Short - long term
2. Water Quality	
a. Continue to assess the effects of altered thermal regimes, total dissolved gases, and water clarity on the timing of spawning, and metabolic rates, growth, and survival of egg through juvenile stages.	Med - long term
3. Contaminants	
a. Determine concentrations of organic and inorganic contaminants in sturgeon, their foods, and habitats.	Short term
b. Encourage/support efforts by entities to assess contaminant effects and monitor contaminant levels.	Long term
4. Habitat Diversity, Connectivity and Productivity	
a. Project future impacts and limitations associated with continuing large-scale habitat changes due to basin development and climate change.	Med - long term
b. Investigate means to restore habitats and natural functions of the Columbia River that are beneficial to sturgeon while also minimizing impacts on other uses of the river.	Short - long term
c. Consider passage alternatives for restoring free movements of sturgeon at such time as new information demonstrates the feasibility, benefits, and lack of risk.	Long term
d. Evaluate feasibility, benefits, and risks of increasing sturgeon population productivity by increasing nutrient availability.	Long term
e. Assess impacts of predators, particularly exotic predators, on early sturgeon life stages.	Short - med term
f. Support examination of toxic/abrasive sediments in suitable rearing habitats.	Short - long term
5. Population Assessment, Monitoring, & Research	
a. Conduct periodic adult stock assessments in transboundary reach.	Short term
b. Continue to investigate feasibility of establishing a failsafe population or an additional recovery area.	Short - med term
c. Conduct regular spawning investigations at key spawning sites.	Short - long term
d. Conduct regular juvenile indexing.	Short - long term
e. Determine recruitment bottlenecks.	Short - long term
f. Develop and improve population analysis methods.	Short - med term
g. Improve the understanding of ecological interactions.	Med - long term
h. Encourage and support applied biological research	Short - long term
6. Education and Outreach	

a. Support active communication and coordination with interested stakeholders to raise awareness of need to protect white sturgeon.	Short - long term
b. Pursue opportunities to link sturgeon recovery activities to other efforts.	Short - long term
c. Implement regular recovery progress reporting to government, aboriginal communities, local agencies, communities, and public.	Short - long term
d. Develop coordinated data and reporting systems to facilitate program implementation	Short - long term
e. Support regulatory mechanisms and planning processes to protect White Sturgeon and their habitats.	Short - long term
f. Monitor sturgeon by-catch in the recreational fishery and develop angler awareness programs to reduce harm.	Short - long term

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 Lake Roosevelt work is complementary to and builds on the goals and objectives of the UCWSRI Plan. 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 in the conservation aquaculture program. 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, elimination of potential early imprinting issues, 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.

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.

7.5 Headwaters Upper Columbia (Keenleyside Dam to Kinbasket Reservoir)

The Headwaters 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 39).

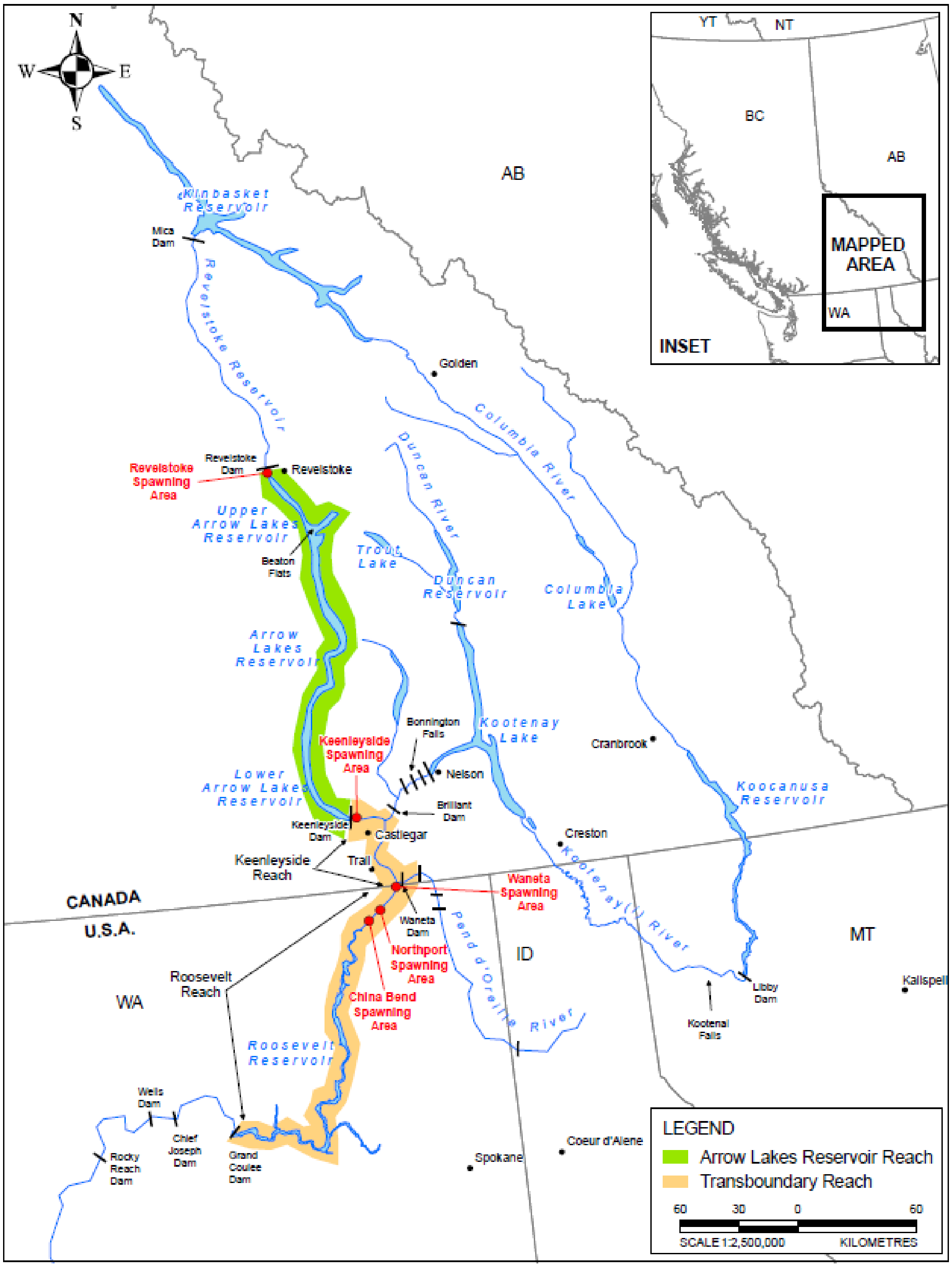


Figure 39. Headwaters Upper Columbia River Management Unit.

Status

The Headwaters Upper Columbia River area above Keenleyside Dam supports a small white sturgeon population that remains at risk of extinction. The majority of white sturgeon in this unit resides in Arrow Lakes Reservoir. The white sturgeon subpopulation has experienced total recruitment collapse (RL&L 1996b, 1998c, 1999b, 2000a, 2000b; Golder 2006b, 2011a, 2011b).

Without immediate, aggressive, and effective intervention, the Headwaters Upper Columbia white sturgeon population is expected to decline below critical thresholds from which recovery may be difficult. Mark-recapture data from 1995 and 1997 to 2003 estimate that a population of 52 (95% CI = 37 to 92) wild white sturgeon (all adults) now inhabits Arrow Lakes Reservoir (Golder 2006b). This population estimate is relatively robust, based on a 29% recapture rate (i.e., 13 of 45 total captures). Other smaller remnant white sturgeon subpopulations remain in other headwater Upper Columbia reaches (Hildebrand and Parsley 2013).

Adult numbers of 500 and 50 have been identified as population benchmarks associated with irreversible consequences in U.S. Endangered Species assessments (Thompson 1991, McLean 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.

Like the wild population segment in the transboundary reach, wild white sturgeon in Arrow Lake Reservoir are large adults. These fish either were trapped in the reservoir following construction of Keenleyside Dam in 1968, or have since moved into the reservoir via the boat lock. White sturgeon have been observed spawning in the Arrow Lake Reservoir reach but the absence of younger fish indicates a failure of natural recruitment (RL&L 2000b; Golder 2011a). In 1999, one spawning event was documented downstream from Revelstoke Dam, the most northerly spawning location identified for white sturgeon in the Columbia River Basin. Since then, spawning has been documented in four of seven years that monitoring has been conducted (Golder 2011b). Despite this documented spawning below Revelstoke Dam, the absence of young wild fish in Arrow Lake Reservoir indicates that natural recruitment has not occurred in this area since completion of Keenleyside Dam in 1968 (Golder 2011a).

Other small remnant white sturgeon populations occur throughout the historical Upper Columbia River range. Two adult sturgeon have been collected during systematic investigations in Slocan Lake (RL&L 1996b, 2000a). Anecdotal reports suggest that white sturgeon were also historically present in Seven Mile Reservoir on the Pend d'Oreille River (RL&L 1995b), Revelstoke Reservoir (RL&L 2000a), and Kinbasket Reservoir (CCRIFC 2010; Westslope 2011). Past attempts to capture white sturgeon in these reservoirs have been unsuccessful, which suggests that sturgeon are either not present or are present only at very low population densities (Hildebrand and Parsley 2013).

The ongoing decline of this sturgeon population 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 Headwater Upper Columbia River sturgeon belies a notion that their longevity provides an extended opportunity for implementation of this recovery plan. In fact, white sturgeon longevity ensures that near-term actions, or inaction, in the following decade will have long-term consequences for the future of this Upper Columbia River population.

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. The remaining river fragments available to white sturgeon in the Headwaters Upper Columbia River may no longer provide the full spectrum of habitats necessary to complete their life cycle.

Today, most white sturgeon reside in the upper half of Arrow Lakes Reservoir. The fish are occasionally observed moving to downstream areas near the middle portion of Arrow Lakes Reservoir. This movement occurs mainly in late summer and early fall when sturgeon are likely to feed on kokanee spawning in tributaries to Arrow Lakes Reservoir. Anecdotal reports suggest that white sturgeon were historically present in the former Lower Arrow Lake (now the lower half of Arrow Lake Reservoir), but assessment fisheries in the lower reservoir have captured only one sturgeon (Prince 2003), which suggests a low level of use of this area. Occasionally, dead white sturgeon have been recovered downstream from Keenleyside Dam; these fish were untagged and died of injuries that may have been sustained during passage through the dam's water release structures (Golder unpubl. data). In addition, one sturgeon that was tagged in the upper reservoir in 1998 was later recaptured downstream from Keenleyside Dam in 2003, indicating that some fish do use or travel through the lower section of the reservoir and are able to successfully pass downstream through the dam's water release structures or boat lock (Golder 2006b; Hildebrand and Parsley 2013).

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, however, can be complex because of interactions with temperature and turbidity. Dam installation and operation has altered the hydrograph (flow volume and velocities) and hypo-limnetic withdrawals have reduced overall river temperatures and delayed warming and cooling rates. The combined changes may reduce the success of, or delay, spawning, egg development, and post-hatch embryo growth and development (Hildebrand and Parsley 2013).

Water Quality

Temperature

Significant temperature changes have accompanied construction and operation of dams and reservoirs. Water temperatures upstream of Revelstoke Dam are similar in summer but warmer in fall and winter as compared to the pre-impoundment period.

Water temperatures in Arrow Lakes Reservoir may affect recruitment success and sturgeon recovery efforts. Available water temperature data indicate that relatively cold water temperatures occurred during the sturgeon spawning, egg incubation and early larval rearing period during both pre-and post-regulation. Recent studies on the effects of temperatures on white sturgeon eggs and larvae indicate that cooler temperatures substantially prolong egg incubation and larval development in comparison to development at more elevated temperatures at spawning areas further downstream (Parsley et al. 2011). This factor, combined with the later than normal spawn timing of white sturgeon in the Arrow Lakes Reservoir reach, results in reduced opportunity for young fish to grow sufficiently to enter the winter period at a size sufficient for survival (Hildebrand and Parsley 2013).

Dissolved Gases

Dam construction and operation has increased dissolved gas to supersaturation levels downstream from several facilities, including Mica and Revelstoke 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. In the past, TGP levels in the Columbia, Kootenay, and Pend d'Oreille Rivers often exceeded the B. C. guideline of 110 percent during spring spills (Clark 1977).

High TDG levels have been shown to produce mortalities and affect larval white sturgeon behavior in laboratory studies, but the significance in the wild and implications for recruitment are unclear. Overall, the effects of TDG on white sturgeon are presumed to be low due to the general selection of all life stages for deeper water habitats. Presently, TDG is not suspected as a primary cause of past recruitment failure or considered a major impediment to future white sturgeon recovery efforts. TDG remains a general concern, however, because of known harmful effects on other fish species and limited information on effects of larval sturgeon in the wild (Hildebrand and Parsley 2013).

<u>Contaminants</u>

The Upper Columbia River watershed in British Columbia 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). Many of these sources have established cleaner operating procedures within the last 25 years; however, a great deal of contaminant input occurred prior to these upgrades and potential effects to sturgeon are unknown. 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.

The UCWSRI recently completed a summary of contaminants in the Upper Columbia River and their potential impact to white sturgeon health (AMEC 2012). Research to date does not indicate that any of the known contaminants in the Upper Columbia River recovery area have directly or indirectly caused white sturgeon recruitment failure (Hildebrand and Parsley 2013; see also McAdam 2012). Contaminant inputs into the Upper Columbia River are presently regulated by federal, provincial, and state agencies and adherence to these regulatory guidelines is assumed sufficient to protect existing white sturgeon.

Nutrients

Together, the elimination of anadromous fish runs, construction of upstream reservoirs, and reduced effluent discharges reduced the historical nutrient inputs into the Upper Columbia River system. Before 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 direct food source for white sturgeon. Upstream reservoirs act as nutrient sinks and reduce downstream transport of nutrients from the upper basin. Matzinger et al. (2007) found that hydraulic modifications due to Keenleyside Dam reduced Arrow Lakes Reservoir productivity by up to 40%. This productivity loss was comparable to the reduction caused by nutrient retention behind Mica and Roosevelt Dams upstream of Arrow Lakes Reservoir.

Reduced nutrient levels have likely reduced the biological productivity of the Upper Columbia River ecosystem. Lower productivity has 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. For sturgeon in Arrow Lakes Reservoir, the effects of reduced productivity may be more significant, particularly when combined with cold water temperatures and a fluctuating reservoir environment.

Water Clarity

Construction of dams and reservoirs reduced turbidity in the reach. These changes in turbidity may have reduced the survival of eggs and young sturgeon. The reduction in cover associated with turbidity leaves young sturgeon more vulnerable to potential predators, especially during larval dispersal and the first few months of life.

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 the mainstem reservoirs flooded large areas of formerly diverse riverine habitat. 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). The mainstem reservoirs also flooded complex habitats that may have provided 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.

The loss of habitat required for white sturgeon survival through early life stages may have particularly affected the population. The changes due to flow regulation and impoundment caused substrate armouring of the riverine reach and altered substrate conditions in the river-reservoir interface area. This likely reduced white sturgeon survival during early life stages by decreasing the suitability of these areas for egg incubation and post-hatch hiding and feeding. Invertebrate prey species may also be unable to find suitable substrate. Sub-yearling sturgeon that cannot find sufficient prey may starve or their growth may be reduced.

Predation and Competition due to changes in Fish Species Composition

The fish community in Arrow Lakes Reservoir consists primarily of native species including 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 (stocked in reservoirs) 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 Revelstoke and Kinbasket Reservoirs include kokanee (introduced), 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.

Changes to the fish community has increased predation on eggs, free embryos, larvae and juvenile sturgeon and reduced survival, likely contributing to recruitment failure. However, identifying whether changes in predation result from an altered fish species composition or the introduction of exotic predators remains challenging because early life stages are likely consumed by both resident and exotic species. Predation levels may also reflect increased vulnerability of sturgeon prey due to reduced cover and turbidity, or increased effectiveness of predators.

Exploitation and Incidental Catch

White sturgeon are vulnerable to overfishing because of their delayed age of maturation (15 years or greater) and longevity (up to 100 years) (Beamesderfer and Farr 1997). Unproductive sturgeon populations, including the Upper Columbia populations, cannot sustain any level of harvest (Rieman and Beamesderfer 1990). In 1994, commercial and sport harvesting of Upper Columbia sturgeon became illegal in British Columbia, and many First Nations people voluntarily stopped their traditional sustenance and ceremonial harvests. Catch and release fishing was closed 1 April 1996.

Plans, Objectives & Strategies

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

Upper Columbia White Sturgeon Recovery Plan

Recovery Objectives

The recovery plan identifies the Arrow Lakes Reservoir reach (Revelstoke Dam to Keenleyside Dam) as one of three potential recovery areas targeted for white sturgeon recovery efforts. The approach will be continually evaluated as numbers of fish present in the entire transboundary reach increase through recovery efforts on both side of the international boundary.

The Arrow Lakes Reservoir reach and Kinbasket reach (upstream from Mica Dam) are also under consideration as possible locations for a future failsafe population. At some point in the future, a failsafe population may be established in an area of the Upper Columbia River basin with suitable habitat that either no longer contains sturgeon or that presently supports a non-sustainable sturgeon population segment. This would involve releases hatchery fish in an area separate from existing recovery areas, which can be used as a future source of white sturgeon to support population abundance and diversity in other recovery areas. Genetic and demographic risks to existing wild populations can be minimized by establishing the failsafe population where the potential for straying can be controlled and monitored (Hildebrand and Parsley 2013).

Recovery Targets

Recovery targets provide interim benchmarks by which progress toward recovery will be measured. A minimum of 25+ years may be required to approach many recovery targets because of the long life span and generation time of sturgeon. Targets identified in the plan are based on population viability guidelines identified in the scientific literature and are similar to those adopted in the draft Canadian National Recovery Strategy for White Sturgeon and in recovery plans for other vulnerable sturgeon populations.

The recovery plan does not establish a minimum interim adult population target for white sturgeon upstream of Keenleyside Dam. Several qualitative recovery targets do apply to white sturgeon in the Headwaters Upper Columbia River management unit:

- Naturally produced recruitment and juvenile population sizes sufficient to support desired adult population sizes in at least two of the three potential recovery areas
- Stable size and age distribution in each population
- Genetic diversity preserved
- Abundance and natural production rates are sufficient to support beneficial uses.

These recovery targets are discussed in Section 7.4.3 for the Transboundary Upper Columbia management unit.

Recovery Strategies

Section 7.4.3 describes the strategies identified in the recovery plan to meet recovery objectives and targets (Hildebrand and Parsley 2013). These strategies control fisheries to prevent impacts on sturgeon, rebuild abundance through hatchery supplementation, and restore natural recruitment.

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 (Hildebrand and Parsley 2013).

Existing Programs and Projects

Since 2007, juvenile hatchery-reared white sturgeon have been released annually into the Arrow Lakes Reservoir reach. Most of these fish are the progeny of wild adult broodstock collected in the transboundary reach and most have been released as 5 to 10 month old juveniles. As of January 2012, the conservation aquaculture program has released 36,643 hatchery-reared white sturgeon into the Arrow Lakes Reservoir reach.

All juveniles have been marked using a PIT tag (primary mark) and scute removal (secondary mark). In addition, 250 juveniles have been implanted with sonic tags in the Arrow Lakes Reservoir reach (50 per year from 2008 to 2012) (Hildebrand and Parsley 2013). Scientists have used a telemetry receiver array to monitor the movements of the sonic-tagged fish released into different portions of the Arrow Lakes Reservoir reach (Golder 2011a). Only 10 hatchery juvenile sturgeon have been recaptured out of the 28,533 hatchery juvenile white sturgeon (including 200 implanted with sonic tags) that were released into the area from 2007 to 2010 (Golder 2011a). Four of the ten juveniles captured have been fish that were equipped with sonic tags at release.

In addition, larval sturgeon releases in the upper section of the Arrow Lakes Reservoir reach began in 2008 when 600,000 unfed larvae were released below Revelstoke Dam through BC Hydro water use planning. Releases of fed and unfed larvae continued in 2010 and 2011. Approximately 1.5 million larvae sturgeon have also been released into the reach (Hildebrand and Parsley 2013).

Fertilization projects have been implemented in Arrow Lakes Reservoir to benefit sturgeon and other members of the aquatic community. Fertilization of the reservoir began in 1999 in response to dramatic kokanee declines. Since fertilization began, phytoplankton, zooplankton, and mysid densities in the reach have increased from pre-fertilization levels. Mysids entrained through Keenleyside Dam are now a primary food source for juvenile sturgeon below the dam (Hildebrand and Parsley 2013).

Further Programs, Actions and Schedules

The USWSRI's 2012 recovery plan identifies a combination of measures to achieve defined recovery goals, objectives, and targets. These measures build on efforts implemented since 2002 that are providing information and increasing white sturgeon abundance in Arrow Lakes Reservoir and other parts of the far Upper Columbia River.

Section 7.4.4. summarizes programs, actions and schedules associated with the initiative to improve white sturgeon populations. Consistent with the recovery strategies, these programs and actions address limiting factors and threats related to fisheries, entrainment, hatchery production, water management, water quality, contaminants, habitat diversity, population connectivity, and system productivity. They also direct further assessments, monitoring, research, information, education, planning, coordination and implementation. Timeframes for each measure reflect short (0-5 year), medium (5-10 year), and long (10- 50 year) term commitments for implementation of measures and expectations of results.

Needs & Uncertainties

Challenges and uncertainties specific to the Headwaters Upper Columbia white sturgeon management unit include:

- Will hatchery-produced mature adult sturgeon ultimately spawn and can natural recruitment be reestablished before the wild fish disappear?
- What is the carrying capacity of available white sturgeon habitat in the river-reservoir transition zone and in each reservoir?
- What is the feasibility of establishing a failsafe population or an additional recovery area in the far Upper Columbia area?

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 (Figure 40). 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.

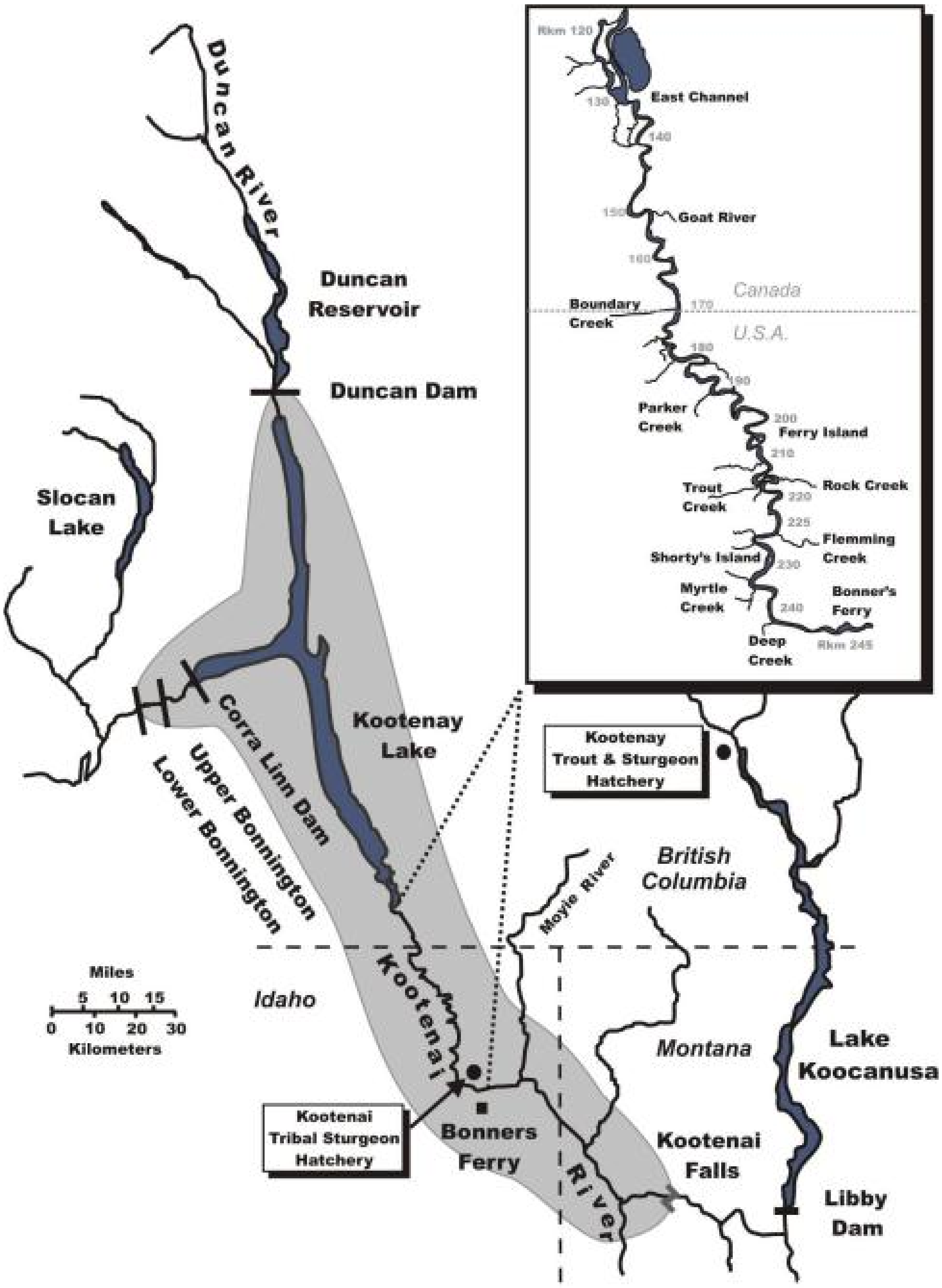


Figure 40. The Kootenay Lake/Kootenai River Management Unit.

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).

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).

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 and Temperature

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 likely altered substrate and hydraulic conditions in the current spawning reach, although the general area represents the upper end of a large alluvial floodplain that was also historically characterized by deposition of fine materials due to its lower gradient (KTOI 2009). 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, high mortality occurs prior to completion of the embryo stage (Anders et al. 2002, 2012; Rust et al. 2010, 2011). However, recent work by the USGS and others has identified the presence of clay shelves or terraces that may provide more suitable conditions for naturally produced incubating embryos (Barton et al. 2012).
http://pubs.usgs.gov/sir/2011/5006/pdf/sir20115006.pdf

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 41). A manual gate system allowing selective vertical withdrawal options was implemented in 1977 to better control the temperature of water released from Libby Dam.

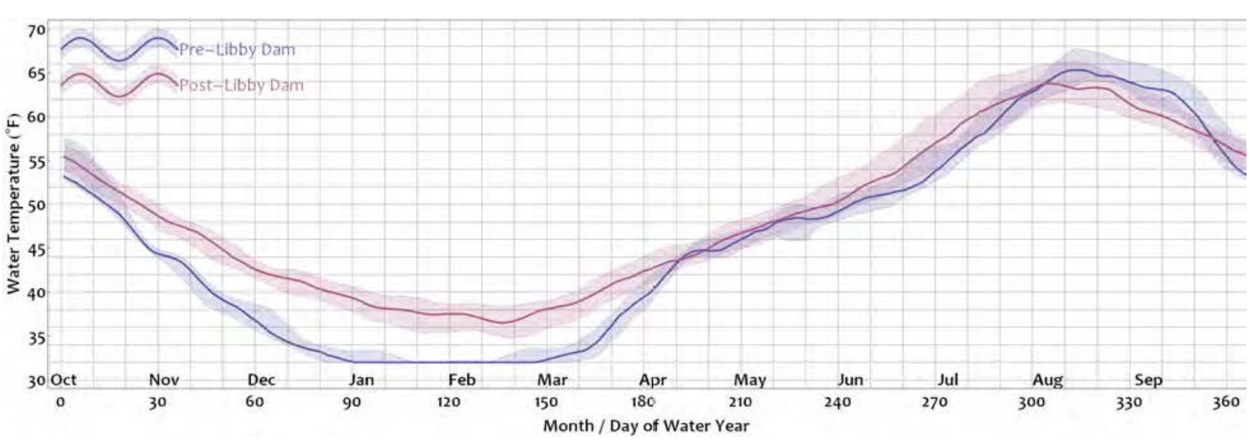


Figure 41. Pre- and post-dam water temperatures for the Kootenai River at Porthill (USGS Station # 12322000) (Figure 3.2. from the Kootenai River habitat Project Master Plan; KTOI 2009).

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). Extensive (120 km) of diking and agricultural conversion also contributed to decreased nutrients when extensive wetland floodplains were disconnected from the River (KTOI and MFWP 2004).

Nutrient levels and fish population abundance in the lower river have plummeted during the past 50 years, principally due to impoundment and loss of large areas of historic floodplain and off-channel habitats following extensive levee construction (Anders et al. 2002; Paragamian 2002). Following levee construction, channelization, wetland drainage, and impoundment during the past century, the Kootenai River has lost its natural flow regime and has experienced reduced diversity and connectivity of habitats and cultural oligotrophication (Northcote 1973, Woods 1982, Anders et al. 2002). Synder and Minshall (2005) documented ultraoligotrophic conditions ($\leq$ 2 ug/l TDP) as a principal causative agent, which prompted an ongoing experimental nutrient addition program for the Kootenai River downstream from Libby Dam, with dosing at the Idaho-Montana border.

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 in some parts of the Basin. 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). Recent work in the Kootenai rider suggests that exposed clay shelves and terraces in the spawning reach may provide conditions for successful embryo incubation (G. Barton, USGS, and P. Rust IDFG, personal communication 2013).

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 web (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, 2013). Populations of many native resident fishes have collapsed, including kokanee and burbot.

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*

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.

Kootenai River white sturgeon recovery efforts are coordinated 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.

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 yet been implemented.

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

In 2005, in conjunction with the Kootenai River White Sturgeon Recovery Team members, the Kootenai Tribe of Idaho developed the Kootenai River White Sturgeon Recovery Implementation Plan and Schedule (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). The 2005-2010 implementation plan was intended to complement and build on recovery plan activities and provide information valuable to an eventual update to the 1999 recovery plan.

The implementation plan included actions to address 1) natural recruitment restoration (flow augmentation, pilot habitat projects, sturgeon spawning and early rearing habitat restoration, and ecosystem restoration); 2) a conservation aquaculture program; 3) monitoring to assess survival and recovery of sturgeon and the ecosystem; and 4) plans to update and revised the recovery plan.

Programs, Projects, Actions & Schedules

The ultimate success of recovery efforts for the endangered Kootenai River 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). Regional co-managers in the Kootenai subbasin are actively collaborating to implement targeted research, monitoring and evaluation, broad-scale habitat restoration, nutrient supplementation, flow and temperature management, and conservation aquaculture programs, which are designed to conserve and restore populations of Kootenai River white sturgeon and the ecosystem they are part of.

Hatchery Program

The Kootenai Tribe of Idaho initiated a sturgeon conservation aquaculture program in 1989 in an effort to preserve an adequate demographic and genetic base for a healthy future population. The goals of the Kootenai sturgeon aquaculture program are to:

- Prevent extinction of Kootenai sturgeon by preserving the locally adapted genotypes, phenotypes, and associated life history traits of the population.
- Restore a healthy age class structure to enhance demographic and genetic viability and persistence of the population.
- Reestablish a sturgeon population capable of future Tribal Treaty subsistence and cultural harvest.

The Kootenai Tribe's white sturgeon conservation aquaculture program began as an experimental program focused on understanding critical ecological and biological uncertainties, identifying limiting factors to white sturgeon natural production, and developing population restoration strategies. Following the listing of Kootenai white sturgeon in 1994 and the development of the Recovery Plan in 1999, and after nearly a decade of annual experimental flow measures at Libby Dam failed to restore natural recruitment, the Tribe began increasing production of Kootenai white sturgeon at the Tribal Hatchery. The hatchery program spawns wild broodstock and rears juveniles for release at 1 or 2 years of age and currently provides the only source of recruitment annually. The conservation aquaculture program plays a critical role as a stop-gap measure to prevent extinction and preserve the remaining Kootenai sturgeon population while habitat restoration activities are designed and implemented (Ireland et al. 2002a, 2002b).

The Tribe's sturgeon conservation aquaculture program identified near- and long-term objectives in order to address conservation-related risks over time (Table 15). 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.

In order to meet both near- and long-term conservation aquaculture objectives the Kootenai Tribe completed a Master Plan[1] in 2009 (revised in 2010) outlining proposed upgrades to the existing Tribal sturgeon hatchery and construction of a new hatchery at Twin Rivers to expand the Tribe's Kootenai River white sturgeon program and to add burbot production facilities. The Tribe submitted their Step 2 document in August 2012 and received approval to move to Step 3 final design in December 2012. Construction of the new facility and upgrades to the existing facility is planned for summer 2013 pending completion of all necessary agreements and permitting.

[1] The Northwest Power and Conservation Council requires a three-step process for review of artificial propagation projects (i.e., hatcheries) proposed for funding by BPA. Step 1 is conceptual planning, represented primarily by Master Plan development and approval. Step 2 is preliminary design and cost estimation, along with environmental review. Step 3 is final design review and construction. The ISRP reviews the proposed projects as they move from one stage of the process to the next.

Table 15. 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.

The original Tribal Sturgeon Hatchery facilities were developed to meet near-term objectives of avoiding demographic extinction with the assumption that natural requirement would be restored by implementing flow measures. However the current Tribal Sturgeon Hatchery is operating at its physical and functional capacity limiting any program operational flexibility in the future. Expansion of the current facilities is not a viable alternative because the available space and water sources are fully utilized.

The new Twin Rivers Hatchery, in combination with the existing Tribal Sturgeon Hatchery, will enable more families to be reared in temperature and density conditions that optimize in-hatchery survival. Additional rearing space will also improve fish health by reducing density-related pathogen transmission and disease susceptibility. Additional space will also support separation of sturgeon progeny groups (families) in the hatchery in order to maintain distinct family lineages until the fish are large enough to be marked with passive integrated transponder (PIT) tags. Additional space is also required to facilitate separate rearing of large and small components of individual families to reduce mortality due to size-based selection in the hatchery. In addition, the new Twin Rivers Facility will include space to accommodate the burbot conservation aquaculture program.

Habitat Restoration

In July 2009, the Kootenai Tribe of Idaho completed the *Kootenai River Habitat Restoration Program Master Plan,* which outlined a framework for implementing the ecosystem-based Kootenai River Habitat Restoration Program. The Kootenai River Habitat Restoration Program is a large-scale, ecosystem-based habitat restoration program to restore and maintain Kootenai River habitat conditions that support all life stages of Endangered Kootenai River white sturgeon and other native fish. The program is being implemented within a 55-mile reach of the Kootenai River in Idaho, over a period of 7 to 15 years. Implementation of the program, in combination with other Tribal and agency programs, will help to restore native fish populations and sustain the Tribal and local culture and economy. The Kootenai River Habitat Restoration Program is being developed in collaboration with multiple agency partners. Funding for the Program is primarily from the Bonneville Power Administration through the Northwest Power and Conservation Council's Fish and Wildlife Program.

The Kootenai River Habitat Restoration Program is designed to address specific limiting factors in each reach of the river including limiting factors associated with river morphology, aquatic habitat, riparian habitat, and existing flow and infrastructure constraints. The Program will be implemented through construction of approximately 8 to 15 individual habitat restoration projects. Each project is designed to address a number of different limiting factors through a combination of treatments. The overall approach is ecosystem-based. The Program includes physical monitoring activities to determine the effectiveness of individual projects in achieving specific goals and objectives, and to support short-term adaptive management actions. Biological monitoring to support longer-term hypothesis testing and monitoring of the biological response to the overall Program is supported through coordination with partners including Idaho Department of Fish and Game, Montana Fish, Wildlife & Parks, and University of Idaho.

The Kootenai Tribe implemented two projects in 2011, and another two projects in 2012 under this Program. All four of the initial projects were in the Braided Reaches of the Kootenai River. Another three projects are planned for implementation in 2013-2014, two in the Braided Reaches and one pilot substrate project in the Meander Reaches. An additional two projects are scheduled for implementation in the Straight Reaches by the town of Bonners Ferry in 2014-2015. The Tribe is also currently developing concept designs for additional out year projects in the Meander and Braided reaches.

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 and cooperation among the co-managers.

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)(Figure 42). 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.

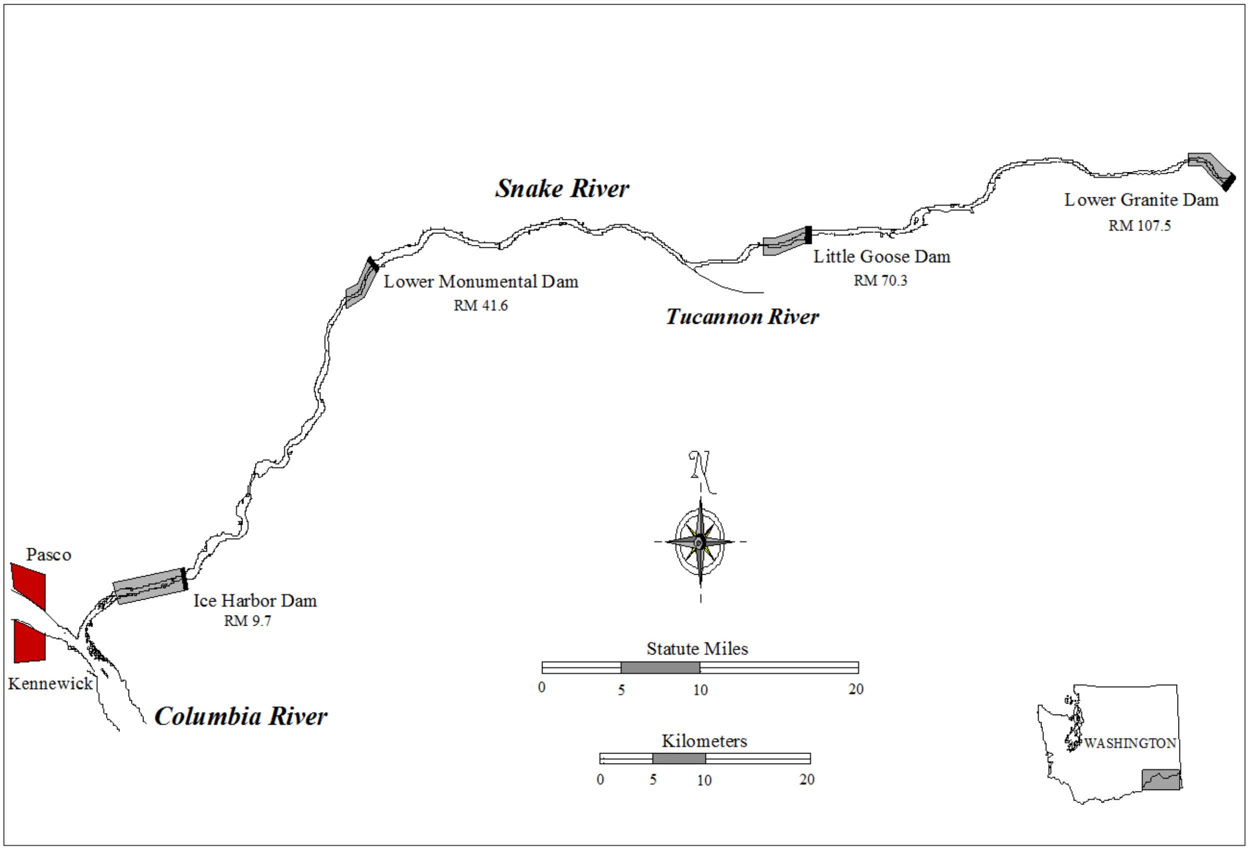


Figure 42. Lower Snake (Ice Harbor Dam to Lower Granite Dam) Management Unit.

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).

Prior to 2012, each of these populations had been assessed just once. WDFW conducted its initial 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. Some preliminary results are included below, with final results expected later in 2013. An assessment of the population in Ice Harbor Reservoir scheduled for 2013 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 (DeVore et al. 1998).

WDFW used a modified Schnabel estimator to come up with an estimate of 1,460 white sturgeon in the 110-209 cm FL (43-82 inches) 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 (21 inches) 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 (DeVore et al. 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 (Table 16). Recruitment index values for these two populations were as low, or lower, than the values observed for the other lower and lower mid-Columbia River populations surveyed (Table 11). Sampling was discontinued in 2005 in response to cuts to the source of funding for this work (BPA white sturgeon project 1986-050-00).

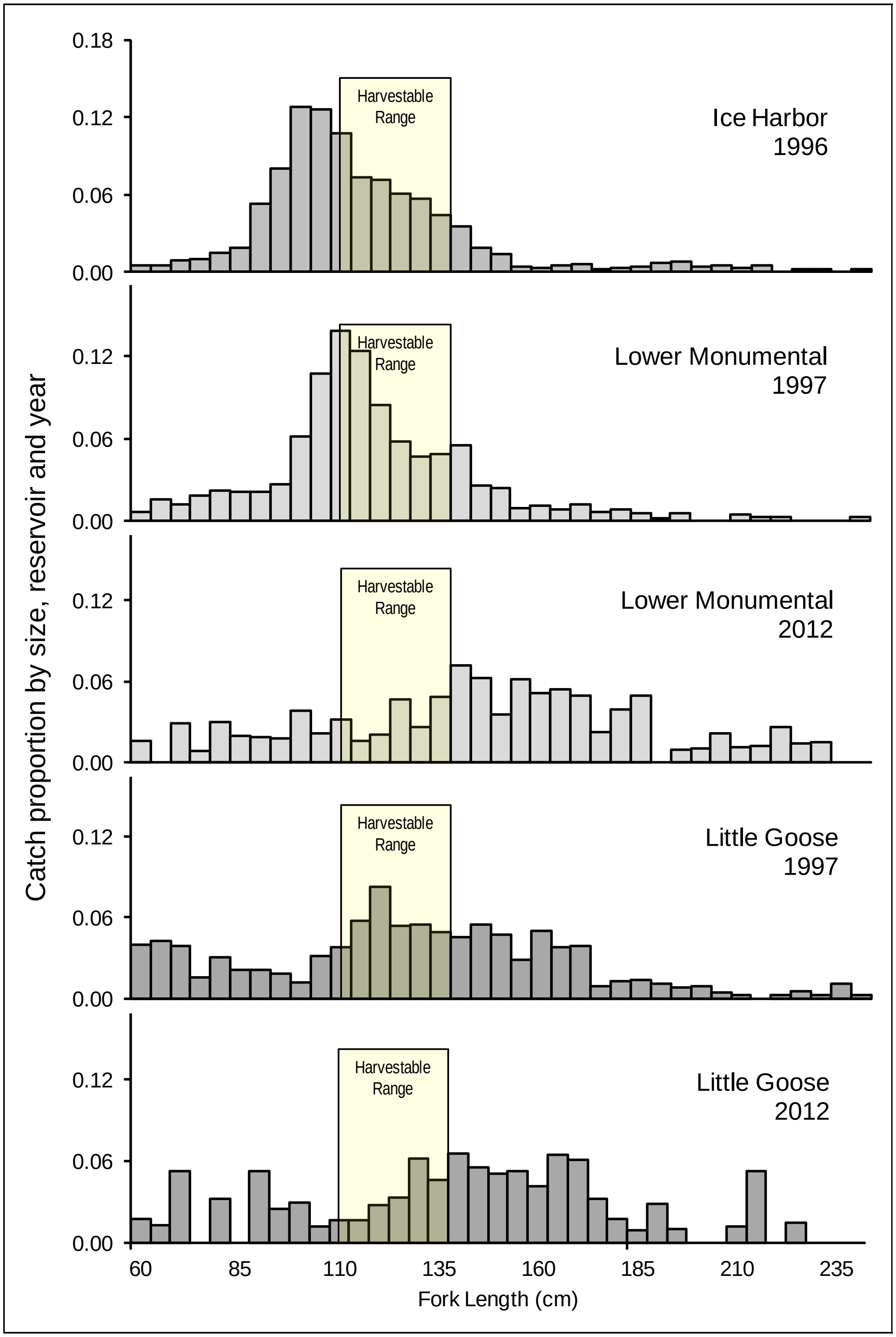
Table 16. Recruitment index values (E_P) for white sturgeon populations in Ice Harbor and Little Goose reservoirs, 1997-2005. E_P=0 is no measurable recruitment. E_P>0 is measurable recruitment, with higher values equating to higher densities of age-0 sturgeon. Sampling for age-0 sturgeon was not conducted in Lower Monumental Reservoir and ended in 2005 in Ice Harbor and Little Goose reservoirs.

Year	Ice Harbor	Lower Monumental	Little Goose
1997	0.00	N/S	N/S
1998	N/S	N/S	0.32
1999	0.03	N/S	0.08
2000	0.00	N/S	0.00
2001	0.00	N/S	0.00
2002	0.00	N/S	0.00
2003	0.00	N/S	0.00
2004	0.00	N/S	0.00
2005	0.00	N/S	0.00

The populations in Lower Monumental and Little Goose reservoirs were assessed again in 2012. Stock assessment crews sampled both Bonneville Reservoir and the two lower Snake River impoundments in 2012, limiting the effort to just two passes in each reservoir. Catch rates in the lower Snake River were lower in 2012 than observed in 1997 during the similar mid to late summer timeframe (Table 17). The size distribution of fish observed in 2012 was comprised of a higher proportion of larger fish than observed in 1997 (Figure 43), indicative of recruitment-limited conditions and of fishery impacts that may be above sustainable levels.

Table 17. Catch per setline-set by period sampled for white sturgeon populations in Ice Harbor, Lower Monumental and Little Goose reservoirs, 1996 and 1997, compared to catch rates in 2012 for Lower Monumental and Little Goose reservoirs.

Reservoir	Period	No. of passes	No. of sets	Catch	Catch per set
Ice Harbor					
1996	May 20 – Jul 11	2	401	442	1.10
1996	Jul 15 – Sep 6	2	478	789	1.65
Lower Monumental					
1997	Mar 31 – Jun 19	2	205	125	0.61
1997	Jun 30 – Sep 11	2	212	608	2.87
2012	Jul 11 – Aug 25	2	120	152	1.27
Little Goose					
1997	Apr 7 – Jun 26	2	236	339	1.44
1997	Jul 7 – Sep 18	2	203	463	2.28
2012	Jul 14 – Aug 28	2	145	143	0.99



FL(cm)	Abundance
54-81	152
82-91	400
92-166	4,160
>166	120
Total	4,832

FL(cm)	Abundance
54-81	274
82-91	212
92-166	3,679
>166	97
Total	4,262

FL(cm)	Abundance
54-81	993
82-91	470
92-166	4,390
>166	640
Total	6,493

Figure 43. Sample size distribution for white sturgeon (≥54 cm fork length) sampled in lower Snake River reservoirs, 1996-1997 and 2012. Ice Harbor Reservoir was not sampled in 2012. Fish were measured to the nearest cm, data are grouped in 5-cm length increments. Size distributions are corrected for the size-selectivity of the setline capture gear. Abundance was estimated in 1996 and 1997, but data was insufficient to estimate abundance in 2012.

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. Downstream movement through the juvenile bypass separators is apparently highest at Lower Granite Dam, with few fish documented at Ice Harbor Dam (Table 18). Few sturgeon have been counted moving upstream through the fish ladders at any of the lower Snake River dams (Table 19).

Table 18. Sturgeon documented at the juvenile fish passage facilities at the four lower Snake River Dams, 2000-2010 (summary courtesy of John Bailey, USACE, personal communication, Feb. 2011 to Glen Mendel, WDFW).

Location	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
Ice Harbor	0	0	0	1	1	1	0	0	1	0	0
Lower Monumental	3	6	10	10	13	30	27	64	87	47	38
Little Goose	11	5	10	12	15	27	39	54	46	99	71
Lower Granite	22	26	24	9	14	19	44	46	73	72	94

Table 19. Sturgeon documented ascending the fish ladders at Ice Harbor (IHR), Lower Monumental (LMO), Little Goose (LGO) and Lower Granite dams (LGR), 2006-2010 (from Steve Richards compilation of fish ladder records, WDFW, personal communication, Feb. 2011).

Year	IHR	LMO	LGO	LGR
2006	11	1	0	2
2007	3	0	1	0
2008	2	0	0	0
2009	1	0	1	0
2010	2	0	0	0

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.

Bennett et al. (1983) found significant positive correlations between water velocity and white sturgeon presence in Little Goose Reservoir, while they found significant negative correlations with aquatic macrophytes and littoral habitats. No correlations were found with water temperature, water transparency and maximum water depth. Vertical distribution of sturgeon sampled in 1979 and 1980 was approximately 20 m in fall and spring, but ranged from <15 to >20 m in summer. Deepwater and tailwater habitats were the only habitat unit types with sturgeon captures in spring and fall, however, during summer they were found in all habitat units sampled including embayments, and shoals, with nearly 90% of observations in deepwater or tailwater habitats. In all seasons sampled, tailwater habitat units contained 78-95% of all sturgeon captures.

Fisheries

Fisheries monitoring in the lower Snake River reservoirs in 1979 and 1980 (Bennett et al. 1983) documented that sturgeon were one of the commonly sought species. Most sturgeon angling occurred in tailwater areas below each dam, but a primary focal area was in the tailwater below Lower Granite Dam. In 1979, 19% of boat anglers in Little Goose Reservoir listed sturgeon as one of their targeted species during April through November. Two other downstream sampling areas in Little Goose reservoir did not include sturgeon as a targeted species by boat anglers. That same year 18% of shore anglers in the Lower Granite tailwater were targeting sturgeon. In 1980, boat anglers fishing the Lower Granite tailwater had sturgeon as one of their targeted species 8% of the time, with no targeting for sturgeon in the downstream sampling areas. However, shore anglers in 1980 in the tailwater area of Lower Granite Dam were concentrating on sturgeon with 70% of all anglers interviewed from March through November targeting sturgeon. None of the downstream sampling areas in Little Goose Reservoir included sturgeon as a target species for shore anglers that year. Success for 59 shore anglers interviewed with completed trips in Little Goose Reservoir in 1980 included catch rates of 0.010 (fish/hr.), with 25% of the anglers successfully catching sturgeon. Average sturgeon fishing trip length was 11.25 hrs. (Bennett et al. 1983).

In 1997, fisheries on the lower Snake River reservoirs were monitored during May though November and compared with the free-flowing middle Snake River from Asotin upstream to the Washington Oregon state line (Normandeau et al. 1999), as part of the Snake River reservoir drawdown evaluation by the USACE. Anglers in the lower Snake River reservoirs caught 718 sturgeon, but only 40 were harvested (17.9 released for every sturgeon harvested). All harvested sturgeon used in analysis from creel interviews were from Little Goose reservoir. Sturgeon caught in Little Goose reservoir comprised 1% of all fish species caught by all anglers during the monitoring period, and sturgeon anglers comprised 0.9% of the 6,147 anglers interviewed in the lower Snake River reservoirs. Most sturgeon fishing occurred by shore anglers in the tailrace areas below Lower Granite Dam, or directly below Little Goose Dam, from May through July. Catch rates in 1997 were 0.038, 0.026 and 0.018 fish per hour, in Little Goose, Lower Monumental and Ice Harbor reservoirs, respectively. Species targeted by anglers consisted of 7.2% sturgeon in Little Goose reservoir (of 498 anglers sampled), 1.0% in Lower Monumental (of 832 anglers), and 0.6% in Ice Harbor reservoir (of 1,964 anglers). Boat angling for sturgeon peaked in August and September, but shore anglers fishing for sturgeon peaked in June. In Little Goose Reservoir, a higher percentage of anglers were targeting sturgeon compared with the two downstream reservoirs (Table 20). In 1997, sturgeon fisheries upstream of Lower Granite Dam were catch and release only, but harvest fisheries existed in the three lower reservoirs. The sturgeon catch rate (fish/hr) was 0.05 and 0.04 for boat anglers in Little

Goose and Lower Monumental, respectively, and it was 0.03 for Ice Harbor reservoir shore anglers.

Table 20. Percentage of boat and shore anglers targeting sturgeon from May through November in the lower Snake River, 1997 (compiled from Normandeau et al. 1999).

Reservoir	Boat Anglers Targeting Sturgeon (%)	Of the Number of Boat Anglers Interviewed	Shore Anglers Targeting Sturgeon (%)	Of the Number of Shore Anglers Interviewed
Little Goose	6.2	243	8.2	255
L. Monumental	0.8	381	1.1	381
Lower Granite	1.1	549	0.0	549

Expanded catch record card estimates of sturgeon harvest in the lower Snake River reservoirs exceed 300 per year in 8 of 14 years (Figure 44), but harvest of sturgeon is relatively low, compared to the Zone 6 reservoirs (Table 7, Figure). Harvest trends lines for each area and the total in the Snake River are declining. Average harvest levels were highest in Little Goose reservoir during the past 14 years (Table 21). Total harvest for the Snake River upstream of Ice Harbor Dam averaged 292 sturgeon (1996-2009). Harvest levels have declined during the past four years compared with the average harvest during the 14 year period. Harvest upstream of Lower Granite Dam is not legal and may reflect errors in the catch record card data entry, or it may be that illegal harvest is occurring and being recorded on the catch record cards.

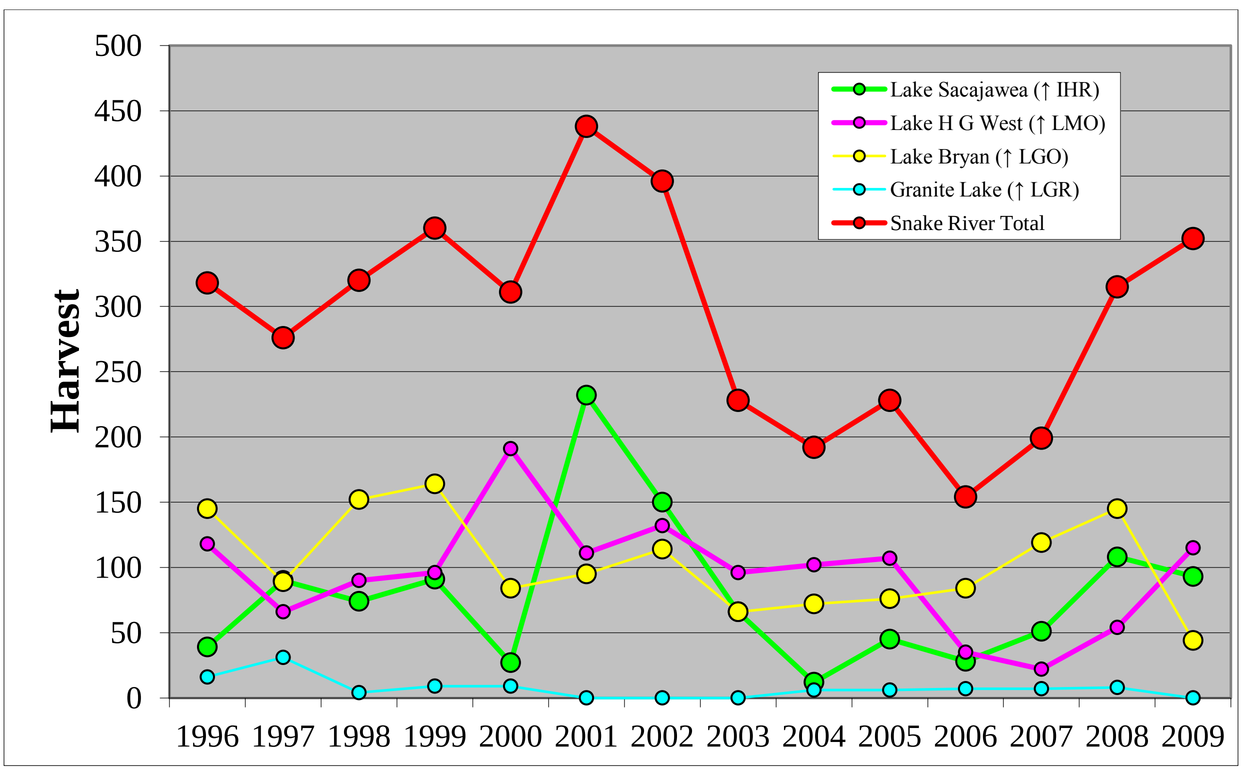


Figure 44. Estimated annual harvest of sturgeon in the lower Snake River reservoirs based on catch record cards.

Table 21. Average catch-record-card estimates of harvest in the lower Snake River reservoirs, 1996-2009).

Reservoir	Average Harvest (1996-2009)	14 YR Std. dev.	Average Harvest (2006-2009	4 Yr. Std. dev.
Lake Sacajawea (↑ IHR)	79	57.7	70	37
Lake H G West (↑ LMO)	95.4	42.5	56.5	41.2
Lake Bryan (↑ LGO)	104	36.7	98	43.8
Granite Lake (↑ LGR)	7.36	8.19	5.5	3.7
Snake River Total	292	82.7	255	93.7

Sturgeon anglers in the Snake River were interviewed by WDFW while creel surveys were conducted for spring and fall Chinook fisheries in designated areas open for Chinook fisheries in 2008-2010 (Table 22). In the Little Goose spring Chinook fishery zone (from just below the Tucannon River upstream to about 1 mile above the dam), most sturgeon anglers were fishing from shore upstream of the dam (67-79% of sturgeon anglers during the three years). The North shore of the tailrace was also well used by sturgeon anglers (15-21%). Most sturgeon anglers below Lower Granite Dam in spring 2010 were fishing between Boyer Park and the dam.

Table 22. WDFW Angler interview data during limited Chinook fisheries in portions of the Snake River open to Chinook fisheries, with sturgeon angler and catch information provided, 2008-2010. All salmon fishing zones were downstream of the dams, except that from Little Goose to 1 mile upstream was also open and sampled).

Year	Area sampled	Fishery Monitoring Period	Number of anglers interviewed Fishing for ALL Species	Number of sturgeon anglers interviewed (% of total anglers)	Interviewed Sturgeon Angler Effort (hrs.)	Catch rate for Sturgeon (kept/rel)
2010	Ice Harbor Dam	20 Apr-11 May	505	0 (0)	0	0/0
	Little Goose	24 Apr-17 May	592	20 (3.4)	182.2	0/0
	Lower Granite Dam	24 Apr-11 May	150	50 (38.7)	386.6	386.6 / 193.3
2009	Little Goose	24 Apr-15 Jun	584	39 (6.7)	260.1	0/0
	Little Goose	1 Sep-15 Oct	761	15 (2.0)	112.8	0/0
	Ice Harbor	1 Sep-15 Oct	306	7 (2.3)	17.5	0/0
2008	Ice Harbor	24 Apr- 15 Jun	310	0 (0)	0	0/0
	Little Goose	24 Apr- 15 Jun	373	19 (5.1%)	94.8	0/0
	Little Goose	25 Sep-15 Oct	427	4 (0.9)	26.0	0/0

Fishery Regulations

The history of recreational angling regulations for white sturgeon in the lower Snake River Management Unit and McNary Dam to Priest Rapids and Ice Harbor dams and is presented in Table 23. Current (2013) regulations allow the harvest of white sturgeon between 43 and 54 inches FL (109-137 cm) in the Columbia River between McNary and Priest Rapids Dams and the Snake River downstream of Lower Granite Dam. Angling for white sturgeon is permitted year-round, except on the Columbia River between the old Hanford town site and Vernita Bridge, which is open to sturgeon angling from February 1 through October 22, and within spawning sanctuaries located 2.5 miles immediately downstream of Priest rapids Dam and 1.5 miles immediately downstream from Ice Harbor Dam, which are closed to angling for sturgeon from May 1 through July 31. Retention of sturgeon is allowed from February 1 through July 31 from McNary Dam upstream to Priest Rapids and Ice Harbor dams and year-round in the lower Snake River from Ice Harbor Dam upstream to Lower Granite Dam. The daily bag limit is one fish per angler and the annual limit was recently changed from five to two fish per angler.

Table 23. History of sport rule changes for white sturgeon in Washington waters of the Columbia River upstream of McNary Dam and the Snake River. In 2009, the size measurement changed from total length (TL) to fork length (FL).

Year	Annual limit	Daily bag limit	Size limit (inches)		Night fishing	Retention disallowed or closed to angling for sturgeon, by area	
			Maximum	Minimum			
Pre-1940	The sport fishery was not regulated (there was a 48-inch minimum size for commercial harvest)						
1940		None, w/ only 3 <48"					
1942		5 fish, 3<48" & 2 >48"					
1950		"	72	30			
1951		3	"	"			
1958		"	"	36			
1971		"	"	"		Retention disallowed	Snake R. upstream of powerline crossing downstream of HWY-12 Bridge at Clarkston
1980		"	"	"	Closed	- -	
1985		2	"	48	"	- -	
1988		"	"	"	"	- -	
1989	15	1	66	"	"	- -	
1992	"	"	60	"	"	- -	
1994	10	"	66	"	"	Retention disallowed	Snake R. upstream of Lower Granite Dam
1996	"	"	"	"	"	Retention disallowed	Col. R. upstream of Priest Rapids Dam
1997	"	"	60	"	"		
2001	"	"	"	"	"	Closed to angling	Col. R. upstream of Chief Joseph Dam
2004	5	"	"	"	"		
2009	"	"	43 FL	54 FL	"	- -	Changed to FL instead of TL for fishery rules
2010	"	"	"	"	"	Retention disallowed Aug.1-Jan.31	From McNary Dam to Priest Rapids and Ice Harbor dams. Closed to angling for sturgeon May 1-July 31 from Ice Harbor Dam downstream 1.5 miles and from Priest Rapids Dam downstream 2.5 miles
2013	2	"	"	"	"	"	"

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.

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).

Programs, Projects, Actions & Schedules

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

WDFW, ODFW and CRITFC have collaborated to conduct white sturgeon assessments in the three lower Snake River reservoirs. Initial population assessments were completed by WDFW and CRITFC in 1996 and 1997. The populations in Lower Monumental and Little Goose reservoirs were assessed again by WDFW, ODFW and CRITFC in 2012. The effort in 2012 was limited to just two passes through each reservoir, limiting the amount of data collected, which proved to be insufficient to generate abundance estimates. 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, when adequate in scope, provide information on current population sizes, and therefore 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.

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 understand movement and how much recruitment occurs in Little Goose reservoir from sturgeon production upstream of Lower Granite Dam.
- 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 (Figure 45) 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.

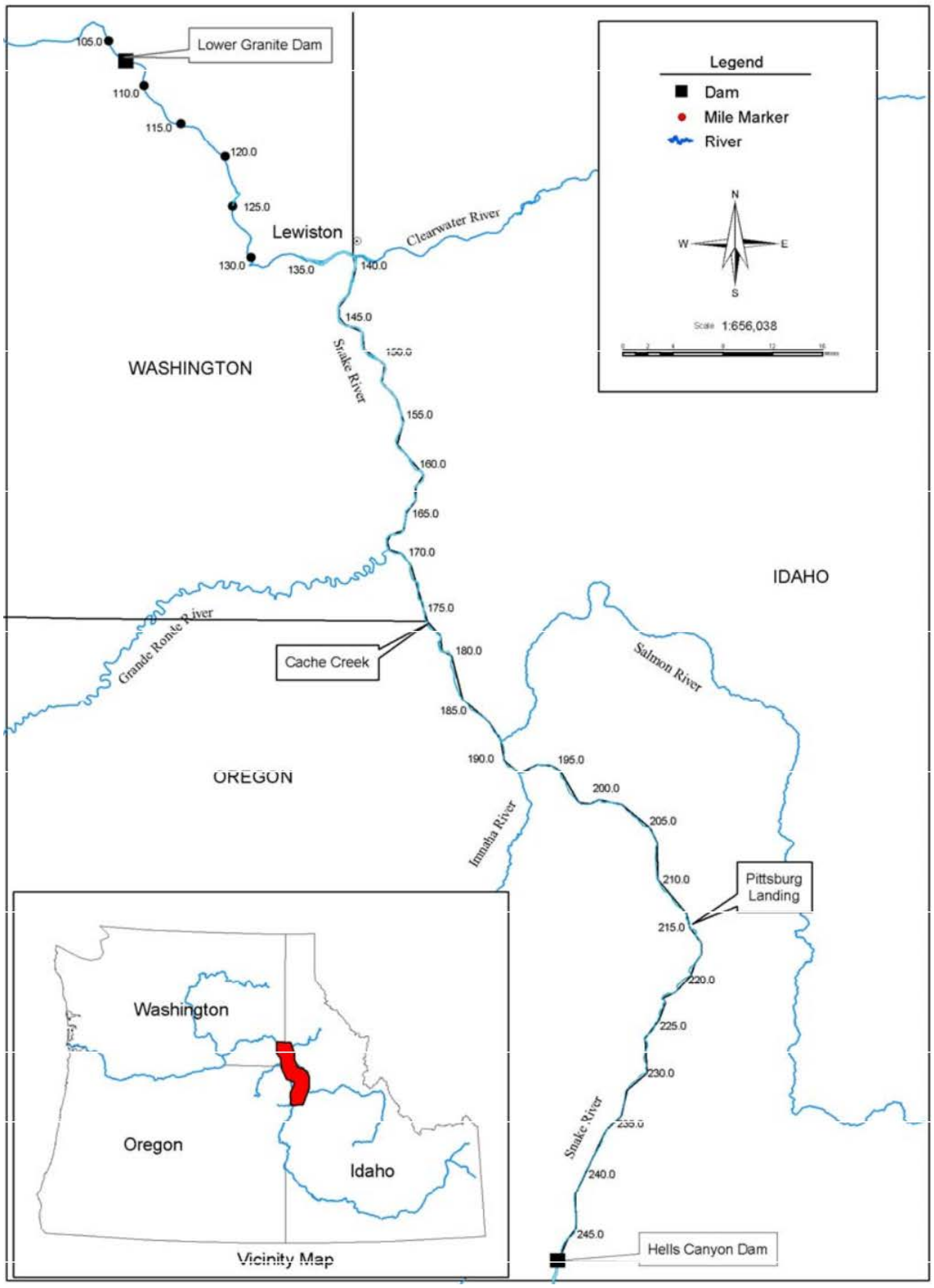


Figure 45. Middle Snake (Lower Granite Dam to Hells Canyon Dam) Management Unit.

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 and all three states have implemented restrictive fishing regulations that prohibit sport harvest.

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). In addition, white sturgeon in Lower Granite pool were studied by Bennett et al. (1993), and Lepla (1994). 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 (Table 24). 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). Total instantaneous annual mortality estimates for sturgeon in the Snake River between Lower Granite and Hells Canyon dams from 1972 through 2000 ranged from 4 to 73%, with a mean of about 12% excluding the high estimate of 73% from 1990-1991 (Table 25).

Table 24. Estimated abundance (N) (95% confidence interval) of white sturgeon in Lower Granite Reservoir and the Hell's Canyon reach of the Snake River.

Reach	Rkm	Year	N	Estimator	Source
Lower Granite Dam site – Hell's Canyon Dam	174–398	1972-1975	8,000-12,000	Schnabel (>45 cm TL)	Coon et al. (1975)
Captain John Creek – Johnson Bar	262–370	1982-1984	2,785 (1,472-4,733)	Schnabel (>45 cm TL)	Lukens (1985)
Lower Granite Reservoir	174–221	1990-1991	1,372 (946-2,166)	Schnabel (>40 cm FL)	Lepla (1994)
		1990-1991	1,524 (1,155-2,240)	Jolly-Seber (>40 cm FL)	Lepla (1994)
		1992	2,785 (1,472-4,733)	Schnabel	Bennett et al. (1993)
		1994	8,173 (5,281-14,401)	Schnabel	Bennett et al. (1999)
Salmon River – Granite Rapids	303–383	1997-2000	1,312 (1,010-1,868)	Schnabel (>70 cm TL)	Lepla et al. (2003)

		1997-2000	1,600 (617-9,471)	Jolly-Seber (>70 cm TL)	Lepla et al. (2003)
Lower Granite Dam – Salmon River	172–303	1997-2001	2,859 (2,574-3,214)	Schnabel (>60 cm TL)	Everett et al. (2004)
		1997-2001	2,139 (839-9,105)	Jolly-Seber (>60 cm TL)	Everett et al. (2004)

Table 15. Instantaneous total mortality (Z) and annual total survival (S) (95% confidence interval) of white sturgeon in Lower Granite Reservoir and Hell's Canyon reach of the Snake River estimated from catch curves.

Reach	Rkm	Year	Z	S	Ages	Source
Lower Granite Dam site – Hell's Canyon Dam	174–398	1972-1975	0.04	0.65	10-20	Coon et al. (1975)
Clearwater River – Hell's Canyon Dam	224–398	1982-1984	0.13	0.88	6-25	Lukens (1985)
Lower Granite Reservoir	174–221	1990-1991	0.73	0.48	6-11	Lepla (1994)
Salmon River – Granite Rapids	303–383	1997-2000	0.14	0.87	6-13	Lepla et al. (2003)
Lower Granite Dam – Salmon River	172–303	1997-2001	0.15	0.86	6-25	Everett et al. (2004)

The studies showed a 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 (36 inches)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.

Population Size Structure

Between 1982 and 1984, 479 white sturgeon captured and measured for total length, which ranged from 45.0 to 280.0 cm (Lukens 1985). The majority (79.5%) of the fish sampled were <91.5 cm TL, and few (2.1%) were >182.8 cm TL. Gill nets and set nets in 1994 were used in Lower Granite Reservoir to capture 799 white sturgeon. They ranged in size from 10-200.2 cm TL, with 94% of the sampled sturgeon <122 cm, and only 0.5% were > 168 cm (Bennett et al. 1999). In 1995, Bennett et al. (1999) captured another 293 white sturgeon (24-202 cm TL) in Lower Granite Reservoir. Between 1997 and 2001, 1,335 white sturgeon captured in the Snake River between Lower Granite Dam (rkm 174) and the mouth of the Salmon River (rkm 303), ranged in length from 27 to 304 cm TL (Everett et al. 2004). There has been a substantial shift in the size composition of the population since the 1970's and 1980's. In the 1970's and 1980's fish <92 cm TL comprised >80% of the catch, while fish <92 cm TL comprised 56% of the catch between 1997 and 2001 (Lepla et al. 2003; Everett et al. 2004). However, within Lower Granite Reservoir, captured sturgeon size structure remained relatively similar from 1990-1992 (Lepla, 1994) through 1995 (Bennett et al. 1999). In 1993, 96% of captured sturgeon were <1.2 m compared to 94% in 1994. Mean length varied from 56.9 cm in 1994, 63.1 cm in 1993, and 67 cm in 1995, compared to 62.3 reported by (Lepla 1994). Bennett et al. (1999) concluded that size structure for sturgeon in Lower Granite Reservoir had changed little in 5 years of monitoring. Bennett et al. (1999) concluded that the 1986-87 year classes had low recruitment to the population.

Mean length at age in the Hell's Canyon to Lower Granite management unit has increased compared to earlier studies. In lower Granite Reservoir mean lengths for ages 5 to 18 years were longer than similarly aged sturgeon in 1992-1975 (Coon et al. 1977) and 1982-1983 (Lukens, 1984). Sturgeon in impounded areas appear to grow faster than in free-flowing river reaches (Bennett et al. 1999; Cochnaurer 1983). Cold water releases from Dworshak Dam and Hells Canyon Dam to improve salmon migration in the lower Snake River may reduce sturgeon growth in this management unit compared to growth rates documented in past years.

Annual Sub-yearling Production Trend

No specific sub-yearling sampling has been conducted; however, the high proportion of juvenile sturgeon (<92 cm TL) in all of the sampling efforts is indicative of regular natural recruitment. The USACE and Bennett (2002) concluded from past studies that the presence of young of year and high juvenile abundance in lower Granite Reservoir indicated recruitment in this river reach, and that the high abundance of juvenile and young of year fish near the upper end of Lower Granite Reservoir also suggests that the reservoir primarily serves as rearing habitat.

Spawning/Early Life History

White sturgeon spawning has been detected in the Hell's Canyon Reach of the Snake River every year between 1999 and 2002 (Tuell and Everett 2003; Everett and Tuell 2003a, 2003b;

Everett et al. 2004). Lepla (1994) assumed no spawning occurred in Lower Granite Reservoir since velocities measured there were 0.0-0.60 m/sec, which are below threshold levels expected to elicit spawning (e.g. 1.0m/sec; Anders and Beckman, 1992).

Habitat Use

Sturgeon tend to use deep areas with relatively high velocities. Coon et al. (1977), Lepla (1994), and Bennett (1999) documented white sturgeon in higher abundance in waters >18 m deep, and higher catch occurred in the upper portions of Lower Granite Reservoir where water velocities are higher. Catch per unit effort was highest in the upstream reaches of Lower Granite Reservoir in spring, summer, fall and winter over six years of sampling (1990-1995). Bennett et al. (1999) noted that high numbers of sturgeon were captured in downstream areas of Lower Granite Reservoir during high inflow years and that "higher inflows may provide more favorable habitat in mid and lower reaches of the reservoir."

Fisheries and Harvest

The Snake River upstream of the powerline crossing below Highway 12 Bridge in Clarkston, Washington (mostly boundary waters with Idaho) has supported a catch and release recreational fishery for white sturgeon since 1971 (Cochnauer 2002). The catch and release regulation was expanded to include the entire Snake River upstream of Lower Granite Dam in 1994. Despite the regulation, in most years some white sturgeon harvest has been reported for the Snake River above Lower Granite Dam on Washington Catch Record Cards (Figure 46). It is unknown if harvest is actually occurring, or people are recording fish they caught and released, or individuals harvesting fish in downstream reservoirs are mistakenly marking the incorrect area. Nonetheless, some illegal harvest may be occurring in the Snake River above Lower Granite Dam, but it is likely at very low levels. Ceremonial and subsistence harvest of white sturgeon by Nez Perce tribal members was resumed in 2002, but harvest levels are unknown (Dillon and Grunder 2008). Normandeau et al. (1999) conducted creel surveys of fisheries both within the impounded reaches of the lower Snake River and the upstream unimpounded reaches. The impounded reaches included to near the town of Asotin. The unimpounded reach fisheries were sampled from September through March of 1997. Nearly 1% (0.9%) of all boat and shore anglers during this fall and winter period were targeting sturgeon (1,575 boat and 787 shore anglers were interviewed). September and March were the highest sturgeon angling months and 20% of all resident fish anglers were targeting sturgeon during this study. Estimated total catch was 122 sturgeon, all from boat anglers, with a directed boat catch rate of 0.050 fish per hour (95% CI= 0.00%) and a total catch rate of 0.040 (95% CI= 0.00).

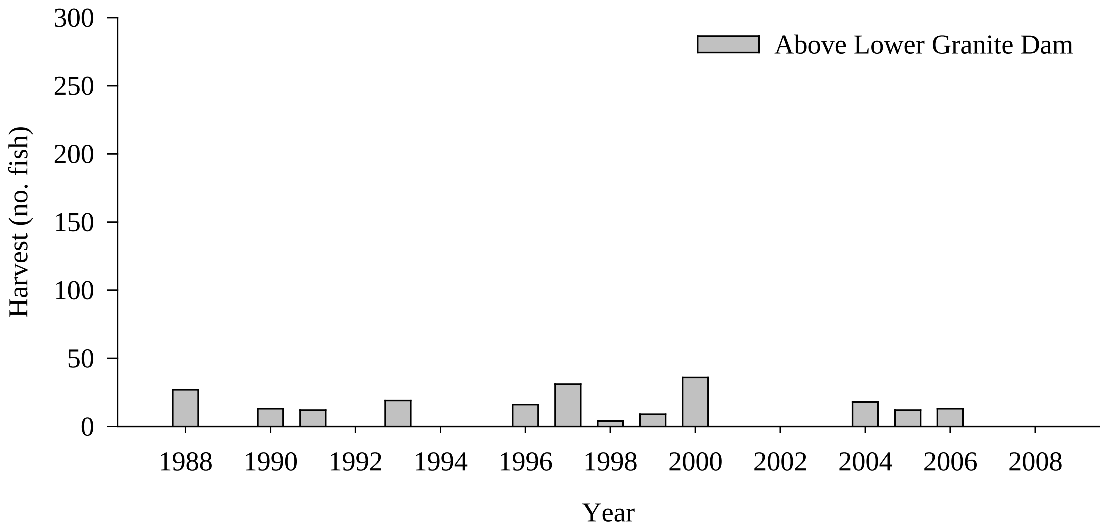


Figure 46. Estimated annual sport harvest of white sturgeon from the Snake River upstream of Lower Granite Dam. The estimated harvest was calculated by expanding the harvest reported on the Catch Record Cards since 1988. Note, closed to retention of sturgeon above Lower Granite Dam in 1994 but some catch record cards indicate harvest after that date - this may be use of inaccurate zone for recording harvest, or it may indicate some harvest continued after the closure in 1994.

***Regulation*s**

Current (2009) regulations by Oregon, Idaho and Washington allow year-round catch and release angling for white sturgeon in the management unit and require angling with barbless hooks. Idaho allows anglers to use of multiple hooks (although not widely practiced) and night fishing for sturgeon, while Oregon and Washington do not. Recently, Idaho changed regulations to require use of a sliding sinker on a lighter test line that will break before the fishing line with the hook. Both WA and OR require sturgeon catch record cards, ID does not. Idaho and Oregon do not allow sturgeon to be removed from the water unless they are harvested, WA does not allow "oversize sturgeon" to be removed from the water.

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 of upper 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). However, the reservoir has been recognized as an important nursery/rearing area with higher growth rates than upstream (Bennett et al. 1993, Lepla 1994). 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

Dissolved Oxygen and Dissolved Gases

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).

Predation

In addition to possible (but unmonitored) fish predation, yearling sturgeon have been stocked with PIT tags; over 80 PIT tags have been recovered from a cormorant colony in the mid-

Columbia reach (J. Murauskas CPUD, L. Hildebrand, Golder Associates, personal communication 2013).

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: 1) maintaining and/or enhancing population viability and persistence of Snake River white sturgeon below Hells Canyon Dams; 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.

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. Dredging of upper parts of Lower Granite Reservoir near Lewiston and Clarkston occurs frequently to maintain shipping ports and river capacity at the confluence with the Snake and Clearwater rivers. WDFW will continue to attempt to protect or mitigate effects of dredging and in-reservoir disposal on sturgeon and their habitat, as well as their primary foods.

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 and other states and tribes. 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, or movements/recruitment into Little Goose reservoir.

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 or within Lower Granite reservoir (mostly within Washington).

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 and WDFG 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.

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.
- Uncertainty regarding whether Lower Granite reservoir acts as a population sink and has a high entrainment and recruitment to Little Goose reservoir. It is also uncertain whether this reservoir is a primary nursery area with higher growth rates that benefit the sturgeon population that spawns in the unimpounded reaches of the Snake River.
- Habitat use, abundance and distribution of sturgeon during the winter work window (December to late March) for evaluation and recommended mitigation of periodic dredging activities near the Clearwater confluence, as well as in-water disposal in the middle of Lower Granite reservoir (near RM 116).
- 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 (Figure 47). 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.

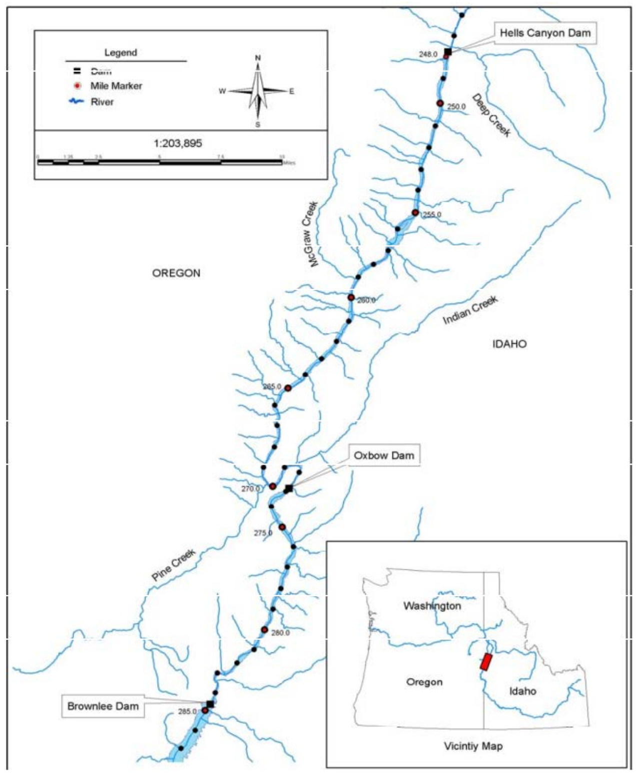
  

  Figure 47. Hells Canyon Dam to Brownlee Dam.

  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 (Figure 48). 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.

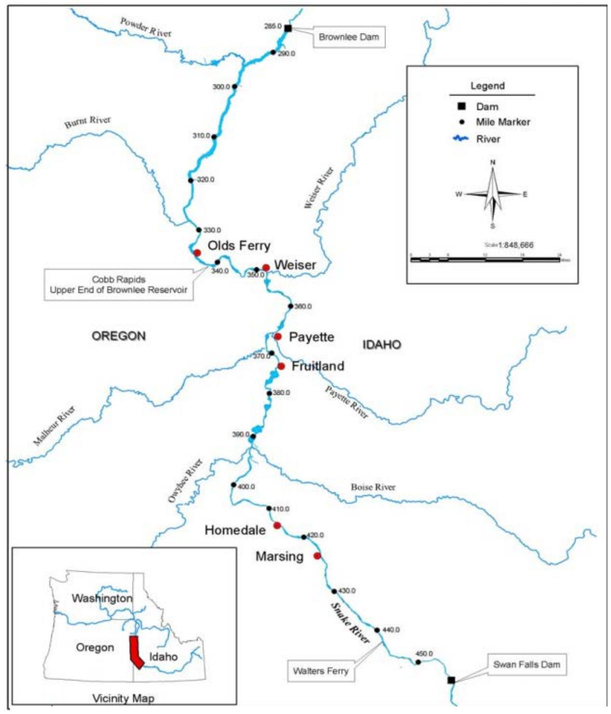


Figure 48. Brownlee Dam to Swan Falls Dam.

- *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 (Figure 49). 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. Strike Dam

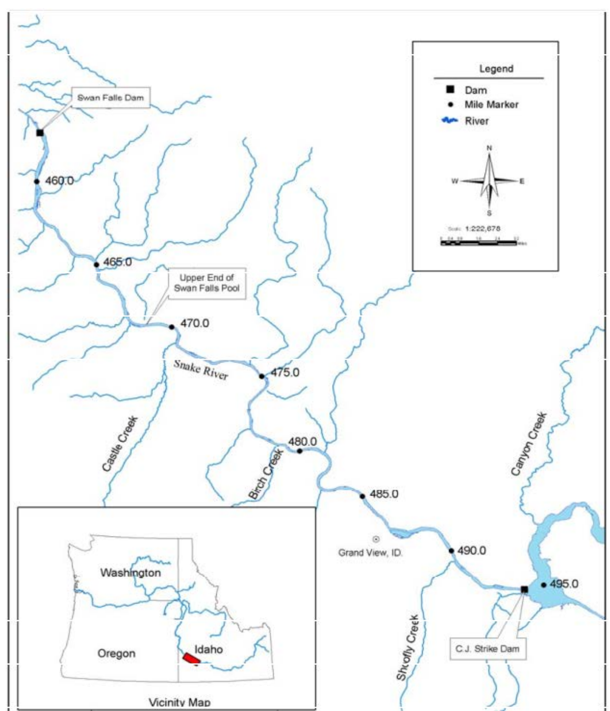


Figure 49. Swan Falls Dam to C.J. Strikes Dam.

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 (Figure 50). 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).

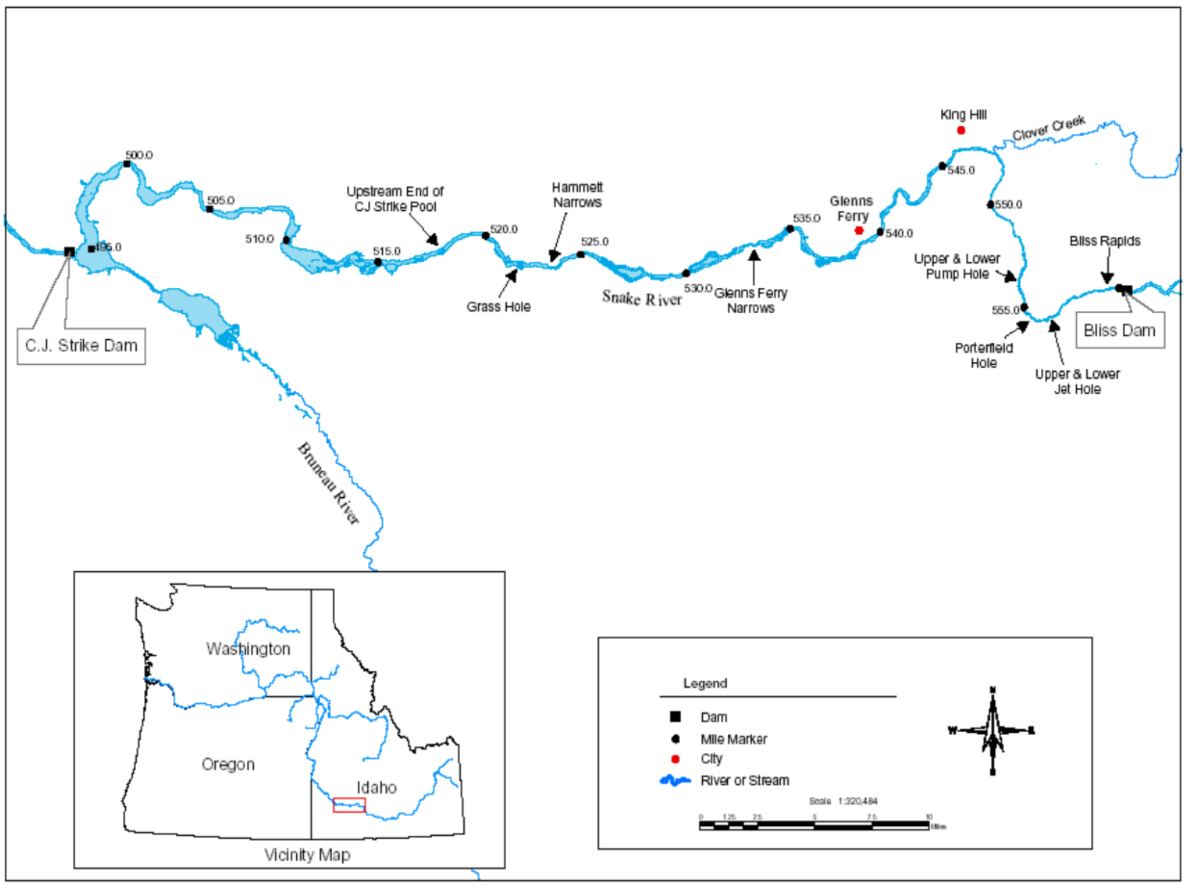


Figure 50. C.J. Strikes Dam to Bliss Dam.

- *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 51).

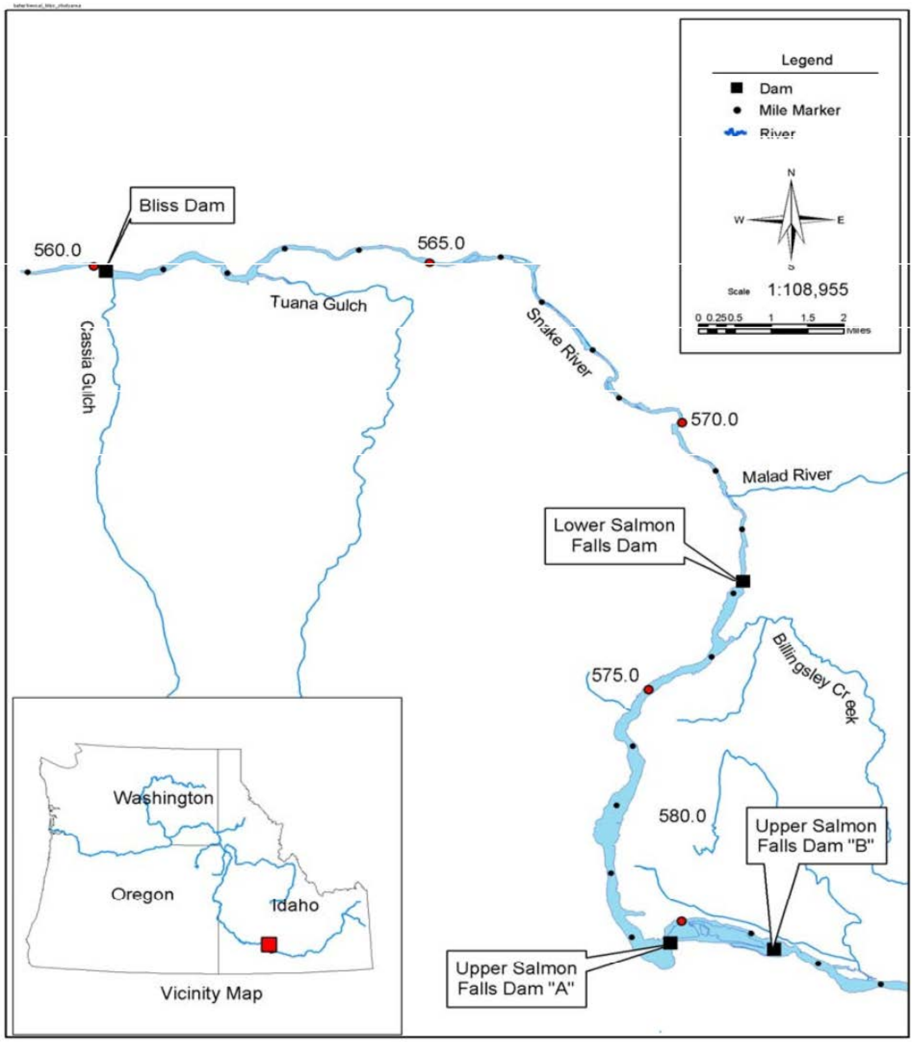


Figure 51. Bliss Dam to Upper Salmon Falls Dam.

- *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 (Figure 52). 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.

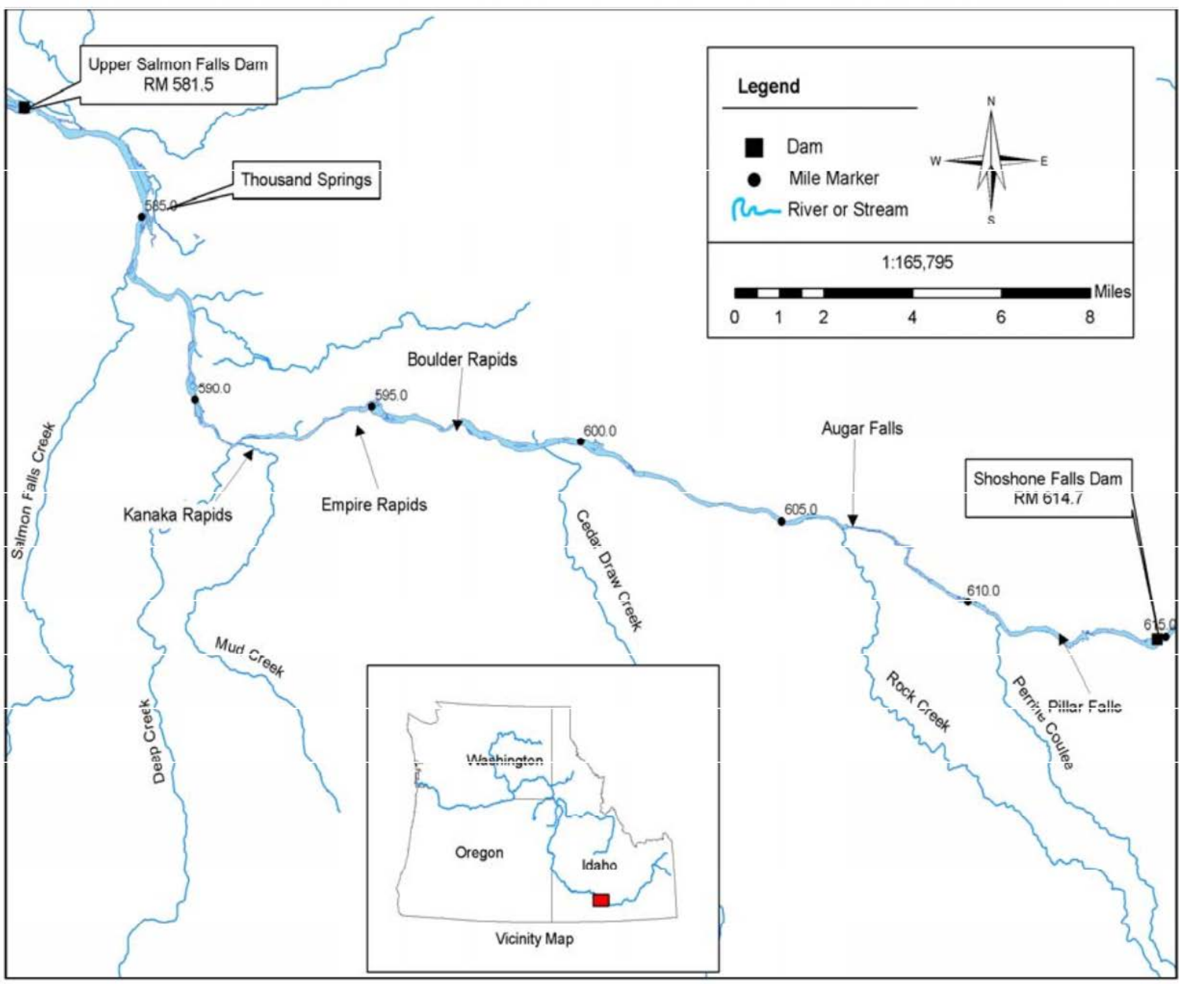


Figure 52. Upper Salmon Falls Dam to Shoshone Falls.

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)(Table 26). 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 26. 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)

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).

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.

Bliss Dam to Lower Salmon Falls

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.

Lower Salmon Falls Dam to Upper Salmon Falls Dam

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: [2, 3]

- 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.

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

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[2] 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.

[3] 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.

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 16).

Table 16. Summary of jurisdiction and/or involvement identified by management unit

	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	--	--	--	--	●	●	--	--	--
Canadian first nations	--	--	--	--	●	●	--	--	--
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 1728). 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 17. Summary of assessment and monitoring information identified by management unit.

	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 a few segments of the upper 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. However, the potential adverse effects of periodic dredging and in-water disposal in various portions of the lower and middle Columbia River, and the middle Snake River, are unknown.

These efforts have contributed to a better fundamental understanding of the biology, population dynamics, and habitat requirements of white sturgeon, which vary across the Basin. Efforts 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 in some areas, and focused actions to protect, mitigate and restore the subpopulations. However, habitat assessments are not ongoing in all management units, and where habitat assessments have been done, the information has not yet been incorporated into assessments of carrying capacity.

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, although some areas have not been surveyed in nearly two decades.
- 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, but missing for the lower Snake River, contribute critical information on genotypic frequencies within the subpopulations, and a baseline for tracking changes that may occur. The lack of genetics and diversity information for the lower Snake River could easily be remedied because tissues are available.
- Translocation of white sturgeon from one reach to another, presently conducted in reaches of the mid-Columbia and upper 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 upper 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 18). Information on limiting factors and threats portrayed in the following reach-specific tables resulted from a combination input for the series of regional sturgeon workshops, empirical research, monitoring, and evaluation from ongoing sturgeon programs throughout the basin, professional judgment, and input to the Framework during the past few years. 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. The potential effects of dredging for navigation and shipping channel maintenance, and associated in-water disposal, on sturgeon, this habitat and their prey or predators is unknown.

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 18. 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 19). Management direction for white sturgeon within the different 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 19. 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 2031). 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. Large-scale habitat restoration actions designed to address limiting factors including habitat complexity, diversity, loss of floodplain and side channel interactions, and attributes from the Libby Dam Biological Opinion (e.g., depth and velocity) within existing operational and infrastructure constrains are currently underway in the Kootenai River in Idaho. Substrate enhancement in current spawning areas of the Kootenai River below Bonners Ferry is also planned for implementation in 2013-2014.

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 upper and lower Columbia River dams to reduce direct mortality of sturgeon during dewatering of turbine draft tubes and fishways for maintenance.

Table 20. Summary of strategies and actions identified by management unit

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, may be able to increase abundance and productivity in areas where habitat conditions are limited. Reproductively ripe male and female spawners have been relocated upstream in the Kootenai River in an attempt to provide spawning over suitable substrates, known as the set-and-jet program.

However, post-relocation telemetry data suggested that the fish exhibited erratic, displaced behaviors, generally did not remain in the intended spawning areas, and provided no evidence of spawning in their relocations reaches (Rust 2011).

- 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. Released progeny from some of these hatchery programs are now nearing initial sexual maturity.

Much remains unknown regarding the abundance and productivity of the various Columbia and Snake white sturgeon populations, and the habitats they rely on (Table 21). 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 21. Summary of research needs and/or critical uncertainties identified by management unit.

	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 in this Framework document.***

   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 over the past 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. With the exception of fish in the Lower Columbia River and the lower three impoundments, most sturgeon sub-populations in the Basin are currently characterized by post-spawning recruitment limitation or failure during a range of early life stages, generally prior to Age-1. The most intensive conservation and recovery efforts have been focused on the endangered Kootenai and the transboundary Columbia populations, where recruitment failure has been ongoing for decades. In both these areas, conservation aquaculture has temporarily forestalled extirpation but recovery as defined in recovery plans, including restored natural production, while a range of ecosystem-based habitat restoration actions are being implemented and have a chance to take hold. 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 immediate conservation and long-term beneficial uses are essential elements of a comprehensive regional vision for white sturgeon management.

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 in some lower basin areas were driven by overfishing but sturgeon recovery throughout the Columbia Basin remains limited in part by hydropower development and operation and their effects on spawning and early rearing habitat conditions. As fisheries were closed or regulated, sturgeon populations increased and stabilized in areas where conditions were suitable for life cycle completion. Where habitat does not support natural recruitment, only small, often-declining remnant subpopulations exist. Historical levels of productivity and use have generally not been achieved in any area due to continuing habitat limitations.

3. ***Large areas of suitable feeding, rearing, and overwintering sturgeon habitat remain throughout most of the historical range upstream from Bonneville Dam. However, while suitable habitat quality and food availability may exist in some of these upstream areas, they may be considerably deteriorated or reduced compared to historical (pre-dam) conditions. Further, post-dam habitat availability and migratory opportunities are now 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 somewhere during the incubation, early life, and 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 also prevents sturgeon from redistributing within and among favorable habitats. However, when favorable habitats have been effectively seeded, substantial numbers of white sturgeon have been produced throughout the system. Thus, remaining unseeded or under seeded 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 provide or improve upstream or downstream passage of sturgeon at dams also risks confounding salmon and steelhead passage or inadvertently allowing the introduction of unwanted exotic species.

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. However, restoring more normal hydrographs and thermographs can also provide additional non-target ecological benefits.***

   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.

   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. A large-scale ecosystem-based habitat restoration effort has been initiated in the Kootenai River incorporating multiple treatments to address morphological, aquatic, and riparian limiting factors and management constraints. Restoration actions include substrate placement, creation and enhancement of pools, reconnection of side channel and floodplain habitat, and riparian habitat restoration. Substrate introduction into the Revelstoke Dam tailrace was conducted to evaluate if lack of suitable substrate currently limits successful spawning and recruitment in the Arrow Lakes population. Results indicated introduced substrate provided higher quality hiding habitat for post-hatch larval sturgeon than adjacent unaltered river substrates. Similar efforts are being planned in the meander reach of the Kootenai River where sturgeon are currently spawning over unsuitable sand substrate. Benefits of these actions will be determined through future monitoring and evaluation efforts.

7. ***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 supplementation program is being developed 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.

8. ***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.

9. ***Sturgeon planning, coordination and project implementation needs within most management units are effectively served by existing groups.***

   Sturgeon projects and activities within different Columbia River Basin 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 the parties involved. 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 30 of 33 impounded sturgeon sub-populations throughout the basin (Figure 20). However, substantial uncertainties remain in our understanding of factors limiting sturgeon reproduction and recruitment, despite more than a quarter century of research. More importantly, 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 habitat diversity; 2) lack of adults; and 3) 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. However, the group also identified the wide range of needs for restoring natural production of white sturgeon throughout the entire Columbia River Basin, including far upstream areas.

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. Genetic population structure has important management implications, particularly for hatchery activities (broodstock selection, effective population sizes, and mating protocols).

Drauch Schreier et al. (2013) published a comprehensive microsatellite-based population structure for the entire range of white sturgeon. This study, based on analysis of over 2,000 samples, provided key findings about white sturgeon population genetic structure that is very helpful to management of the species throughout its range, including the Columbia Basin. Authors reported that an isolation by distance pattern was exhibited for by white sturgeon across the Columbia Basin, which was supported by among-drainage population structure analysis results. Results provided little genetically-based support for managing sturgeon in each river reach (between dams) in the Columbia-Snake drainage as separate populations as adjacent reaches showed little to no genetic divergence. Thus, results of this comprehensive analysis support the use of five genetic management units further described in the following sections of this document (Figure 19). These five genetic managements have somewhat flexible geographic boundaries but contain groups of fish that are more genetically similar to each other than to fish in adjacent units, with genetic divergence increasing with increasing geographic distance.

In addition to spatial genetic population, an ongoing issue throughout the upper basin is the potential for "genetic swamping" of the remaining wild sturgeon by those produced and stocked from one of the existing or proposed hatchery programs. Use of detailed parentage, kinship, and relatedness testing is now routinely performed with hatchery programs to address the genetic composition and relative risks of various aspects of propagation programs,

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 Conservation, Restoration & Mitigation Alternatives

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 should emphasize short-term recovery objectives and where feasible and appropriate, longer-term beneficial use and mitigation goals.

1.2. Additional resources will be necessary to meet goals consistent with the regional vision for sturgeon identified by this framework document.

Limiting Factors

1.3. 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.

1.4. 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.

1.5. 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:

   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.

1.6. Experimentally evaluate benefits of flow measures for sturgeon.

1.7. Pursue other opportunities for operational management to improve conditions for natural recruitment of sturgeon where feasible. Operational opportunities may address:

   a) Quantity, quality, and distribution for white sturgeon spawning, incubation, and early life stage development and dispersal criteria.

b) River flows that minimize predation on white sturgeon early life history stages.

1.8. 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.

1.9. Implement experimental habitat restoration measures to address limiting factors for white sturgeon where appropriate (e.g. substrate and river function limitations identified in the upper Columbia and Kootenai rivers).

1.10. Implement experiments to evaluate effects of contaminant exposure on white sturgeon productivity.

1.11. Implement contaminant remediation measures to benefit white sturgeon where appropriate.

1.12. Avian, mammal, and fish predation on various life stages of sturgeon are important limiting factors in some areas of the basin. Programs to evaluate and if warranted design and implement predator or predation control measures should be considered.

1.13. Food resource limitation is another limiting factor for sturgeon production in some parts of the basin. Assessment of nutrient limitation and resource routing (food web analyses) in the context of hydro regulation should be considered in affected areas.

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 responsibly regulate harvestable subpopulations as a mitigation measure for hydro system impacts.

1.17. Provide adequate law enforcement personnel to enforce current laws/regulations that protect white sturgeon and their habitats.

Hatcheries

1.18. Utilize and adaptively manage conservation hatchery programs as interim measures to avoid extinction of sturgeon populations, where appropriate.

1.19. Be conservative and responsible in establishing protocols for source populations and numbers of hatchery fish released. Learn from ongoing hatchery efforts in other areas.

1.20. Utilize experimental hatchery releases and monitoring to assess ecological factors and population productivity limitations.

1.21. Implement hatchery practices and develop production goals consistent with environmental carrying capacity.

Research, Monitoring, & Evaluation

1.22. Integrate status and trends, and action effectiveness monitoring to allow effective adaptive management of sturgeon programs.

1.23. Assess cross-basin information needs, such as food habitats, ecological interactions, maturation biology, genetic stock structure, and bioenergetics.

Outreach

1.24. Continue to support state, tribal, and public involvement processes for outreach, information, and education functions related to sturgeon conservation, management and mitigation in each management unit.

1.25. 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.

1.26. Endorse and employ coordinated regional and local data management strategies to assure the security, quality and accessibility of white sturgeon data sets.

1.27. Continue to rely on a dispersed data management and sharing system among sturgeon management units for populations that are functionally isolated.

1.28. Implement education programs to inform the public of the consequences of over-harvest of long-lived white sturgeon.

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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 web

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.