An underwater photograph of a white sturgeon swimming in a river. The fish is the central focus, shown from a side profile as it moves through the water. The background is a slightly hazy, greenish-brown riverbed with some rocks and sediment. The lighting is natural, highlighting the texture of the fish's skin and its long, pointed snout.

# Lower Columbia River and Oregon Coast White Sturgeon Conservation Plan

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# Section 1. Executive Summary

Naturally producing white sturgeon inhabiting the Columbia River downstream of Bonneville Dam are ecologically, culturally and economically important to the Pacific Northwest Region. The population segment in this river reach is healthy, abundant, supports commercial and recreational fisheries, and provides other societal benefits to the region. The high public interest and importance to local communities make white sturgeon a conservation priority for adjacent states, federal, and Tribal agencies carrying out fish and wildlife management responsibilities in the Pacific Northwest Region. Oregon Department of Fish and Wildlife staff has worked with regional white sturgeon experts, stakeholders and the public to develop this lower Columbia River White Sturgeon Conservation Plan (hereafter “Conservation Plan”) that 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 will also benefit white sturgeon populations and future management efforts in the greater Columbia River Basin by exemplifying an approach to assessing and monitoring the long-term population viability of this long-lived species. The Conservation Plan synthesizes pertinent white sturgeon information from current monitoring efforts and available scientific literature. It is intended to identify and prioritize habitat, management, and research needs specific to white sturgeon in the lower Columbia River and Oregon Coast.

While this population segment is not at a conservation risk, continued preservation and efforts to build a healthy population that is capable of sustaining robust and meaningful harvest opportunities is essential. 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. The Conservation Plan is intended to avoid serious depletion of the population segment by determining measurable biological criteria (benchmarks) for key population attributes that describe both, a desired population state and the conservation state. Major biological attributes are: abundance, distribution, diversity, productivity, habitat, and persistence. In addition, we developed secondary criteria for growth, condition, and survival, including specific metrics for harvest management and natural mortality.

The Conservation Plan has been developed in collaboration with federal and tribal sturgeon researchers, state management partners, and the public to address six fundamental questions:

1. What do we consider to be a healthy and harvestable population (**Desired Status**)?
2. What do we consider thresholds at which the population is at some risk of extinction, because its performance has become unpredictable (**Conservation Status**)?
3. What is the current status relative to the conservation thresholds (**Current Status**)?
4. What are the key factors influencing the current population status (**Limiting Factors, Threats, and Constraints**)?

5. What can we do to address these factors in the near-term and in the long-term (**Recommended Management Actions**)?
6. How will we know whether we are making progress toward the desired status (**Action Effectiveness Standards and Research, Monitoring and Evaluation**)?

We developed a population viability analysis model (PVA) to effectively measure and assess progress toward the desired population state over time. The model allows us to estimate the effects of certain inputs, e.g., starting abundance, growth, mortality, on future population abundance. While overall desired status will not be fully attained until all metrics exceed the threshold, abundance-related metrics are vital to assess adult (fork length >65 inches) and sub-adults (fork length 38-65 inches). By using the PVA model, empirical observations, and scientific literature, we developed specific benchmark values (thresholds) for abundance and productivity metrics. Desired abundance and productivity levels were developed by modeling future population performance under current to maximum sea lion predation, recent to observed poor egg-to age-1 survival rates, and a sustainable fishery exploitation rate. As a secondary qualitative assessment, the resulting population equilibrium values were also compared to biological reference points for long-lived marine species such as Pacific rockfish to ensure population sustainability.

Although none of the biological attributes discussed within the Conservation Plan are trivial, abundance and productivity are crucial predictors of viability. White sturgeon generation times are on the order of 25+ years, and the prolonged timeframe expected for a population response is not easily grasped. For example, achieving the desired abundance status may take up to 20 sturgeon generations, or 500 years, a timeframe that loses meaning for most people. Therefore, we established desired abundance levels at certain checkpoints in the near and longer term future. These interim target values for adult white sturgeon range from 9,250 in 3 years to 16,250 in 500 years, and for sub-adult white sturgeon desired abundance ranges from 257,000 in 3 years to 368,000 in 500 years. Fluctuations up and down over the years are expected and typical of white sturgeon population performance.

Egg-to-age-1 survival estimates are an important measure of productivity, but estimates depend on back-calculations from the abundance of 5 and 6 year-old white sturgeon. Thus current abundance estimates allow us to back-calculate egg-to-age-1 survival up through 2004. To monitor productivity in the near term we are using the results of our age-0 indexing activities (which assess the relative abundance of white sturgeon less than one-year old) and the length frequency distribution of the population. We have set our desired age-0 catch rate at our recent observed high value of 5.66 age-0 white sturgeon caught per net, and the desired length frequency distribution as a population that is comprised primarily of juvenile fish ( $\geq 95\%$ ). Sub-adult and adult fish make up a smaller proportion of the desired length frequency distribution with approximately 4% and less than 1% respectively.

We have also developed conservation status criteria to detect and recognize signs of a declining population whose trajectory has become unpredictable. Thresholds for conservation status represent a lower level of biological health and should not be viewed as the lower end of an otherwise healthy population. Instead, they represent early warning indicators below which conservation actions, likely already being implemented if the population segment were on a

trajectory toward conservation status, are required. Conservation thresholds set and describe a population level that must be avoided if possible.

For example, we determined abundance conservation status levels by applying the modeled equilibrium size structure to various starting population sizes in the PVA model. If the starting population size, or if the modeled population size at any point during the 500-year modeled run, was less than 450,000 fish (of which 31,000 fish are sub-adults and 3,900 are adult white sturgeon) the PVA model predicts population segment failure in  $\geq 5\%$  of model runs. These metrics are viewed as conservative, because contrary to the constant parameters of the modeling effort, actual interim status checks indicating metrics at or near the conservation status will warrant adaptive management strategies, including further analyses and corrective actions to stop and reverse declining trends.

Population modeling indicates that total recruitment failures need to occur in consecutive long-term blocks to constitute a risk to the population. Our modeling data and published scientific literature were used to determine an appropriate length frequency distribution threshold for the conservation status. A white sturgeon population in which 60% or less of the population is composed of juveniles indicates a population with productivity issues.

The current estimate of 89,000 white sturgeon of 38 – 65 inches fork length is based on ongoing monitoring efforts in the lower Columbia River. This estimate is below the desired status goal of 257,000 sub-adult white sturgeon in 2014. The current estimate is accounting for the sub-adult population within the lower Columbia River proper and does not take into account those fish residing in coastal and estuarine waters outside the Columbia River or in the Willamette River upstream of Willamette Falls. However, the current estimate is substantially above the conservation status level of 31,000.

The current adult fish abundance estimate of 11,000 exceeds our 2014 desired status goal of 9,250, although not yet exceeding the eventual 500-year desired status threshold. This estimate is clearly also in excess of the conservation status level. Continued annual monitoring and fish tagging efforts will provide for length frequency distribution data which, combined with fisheries dependent stock assessments, enable the reliable tracking of population trends over many years, as necessitated by the extraordinary longevity of white sturgeon.

Annual age-0 indexing activities have documented reach specific and annual recruitment levels that exceed the conservation status threshold and meet the desired status threshold; however the first time we witnessed the 5.66 fish/net level was in 2009. These trends need to be evaluated over intermediate 3-5 year, and longer 5-10 year periods. The 2010 estimate of the length frequency distribution for lower Columbia River white sturgeon indicated a population that was comprised of approximately 91% juveniles, 8% sub-adults, and 1% adults and therefore near the desired status.

When looking at the current status of the full suite of biological attributes, it is clear that the lower Columbia River white sturgeon population is not at its desired status. However, it is equally clear that it is above the conservation status, as all biological attribute metrics are above the conservation status thresholds.

Although we find the lower Columbia River white sturgeon population to be healthy and not at risk, critical constraints, limiting factors, and threats do exist that could compromise the long-term health of this population segment and influence the ability to institute meaningful fisheries.

These factors include both biotic and abiotic impacts. The chief biotic concern is pinniped predation; Steller and California sea lion and harbor seal predation on white sturgeon in the Columbia River downstream of Bonneville Dam has increased sharply in recent years. Between January of 2006 and May of 2010, annual estimates of white sturgeon predation have increased from 442 in 2006, to 2,172 in 2010. A concurrent decrease in the size of white sturgeon preyed upon by sea lions has been witnessed, dropping from  $\geq 47\%$  of preyed upon white sturgeon being greater than 48 inches TL in 2006 to approximately 20% being larger than 48 inches TL in 2009. The increase in numbers and decrease in size of fish killed is of great concern. The actual magnitude of marine mammal predation related losses of lower Columbia River white sturgeon is currently unknown. Present loss estimates generated through observations at Bonneville Dam are considered minimum loss estimates, because pinniped predation is known to occur prior to and after the sampling periods each year, and observations are limited to the Bonneville Dam Tailrace, hence predation occurring elsewhere in the lower Columbia River is unaccounted for.

Among the most concerning abiotic factors are Columbia River flows and flow variability associated with the construction and operation of the federal hydropower system (FCRPS). Before the development of the FCRPS, river flows were characterized by high spring runoff from snowmelt and regular winter and spring floods. Post construction spring freshets have been reduced by more than 50% and winter flows increased by 30%, as water is managed for flood control, power generation, irrigation and recreational use. Flows in the Bonneville Dam tailrace can vary hourly and daily between high levels during peak power generating activities and low levels during off-peak demand, resulting in substantial areas of riverbed being repeatedly dewatered. White sturgeon eggs and larvae are deposited in, or transported to, shallow water habitats after spawning. The change in the flood cycle and the repeated dewatering of these shallow habitats during power-peaking activities directly impacts the success of spawning and recruitment of age-0 white sturgeon.

We have developed a suite of recommended management actions designed to remedy critical constraints, limiting factors, and/or threats. Many of these actions may effectively target one or more factors, however, only a few of them are instantly available to fishery managers, while others have a longer time horizon. The tool most readily available to reverse declining trends in population abundance is the use of restrictive fishery management actions, which are instant and highly effective. If the exploitation rate were reduced from the currently modeled sustainable rate of 16% to 10.8%, the modeled population response in 15-500 years is an estimated 125 – 180% increase in the adult and sub-adult population segments over the healthy, but not fully harvestable trajectory. If all harvest was suspended, the modeled population response in 15-500 years is an estimated 215 - 350% increase in those same population numbers. Moreover, the fishery encompasses a considerable conservation buffer within itself. If the population was compromised in terms of both abundance and productivity and nearing conservation status, reducing harvest rates can substantially reduce population risk. Longer-term actions that are potentially as powerful as fishery management actions include, but are not necessarily limited to: implementing and enhancing management actions to reduce marine mammal predation on white sturgeon in the lower Columbia River, operating the hydro-system to optimize spawning and rearing habitat and white sturgeon recruitment while minimizing direct and indirect mortality, and exploring artificial supplementation options to augment fisheries and to mitigate for biological attribute metrics near or at conservation levels.

Due to the prolonged life history of white sturgeon, generations and population responses are measured in decades. Within the concept of the desired status, it could take up to 20 sturgeon generations, or 500 years, for all biological objectives and goals to be met successfully. More importantly, our modeling approach indicates that in time, these goals are reasonable and achievable. That being said, 500 years is clearly beyond a timeframe easily grasped and planned for. More proximate assessments are needed to measure the population segment health. Because abundance and productivity are the important and highly sensitive predictors of viability, we developed curves that jointly plot abundance and productivity, allowing instantaneous assessments of population health. If abundance and productivity intersect at a point above the curve, the population is considered healthy. Although fisheries managers would be alarmed, should either abundance or productivity metrics fall below the curve and into conservation status, the biggest population risks are evident when both of these metrics fall into conservation status concurrently. Present day estimates of abundance and productivity indicate that the population is substantially above this area of concern.

Because of the importance of fish abundance to population viability, the ecological and economic importance to the region, and the timeframes associated with white sturgeon life history, a White Sturgeon Technical Management Team will be convened to review the series of performance measures for the abundance metrics presented in this Conservation Plan. These measures allow for regular assessment of the population status. These assessments could indicate (1) a population segment on track to reach desired status, (2) a segment that is not changing from the current status and therefore neither fully harvestable nor at the conservation level, or (3) the population segment is trending below a healthy level or toward conservation status.

Due, in part, to the legacy effects of past actions, we expect the adult abundance metric to decrease within the next 15 years. However, as long as the rate of decline and the estimated number are not exceeding the modeled projections, this decline is not indicative of a population at risk. If, during annual assessments and at pre-determined checkpoints, fish abundance metrics fall below expected healthy and harvestable ranges, the White Sturgeon Technical Management Team will develop and recommend the implementation of temporary management actions to redirect progress towards abundance checkpoints and eventual attainment of desired status.

## Section 2. Introduction

Lower Columbia River white sturgeon *Acipenser transmontanus* are uniquely adapted to the large river systems which they inhabit (Beamesderfer and Farr 1997) and the lower Columbia River supports the most productive white sturgeon population in the world (DeVore et al. 1995). White sturgeon provide commercial and recreational fisheries, are an ecological cornerstone, and are culturally important to regional Native American Tribes. This ecological, economical, and social importance makes them a conservation priority species for the State of Oregon and for the entire Pacific Northwest. Consequently, the Oregon Department of Fish and Wildlife (ODFW) has prepared a conservation plan that maps out the attributes of a healthy, viable and productive white sturgeon population in the lower Columbia River downstream of Bonneville Dam and along the Oregon Coast. The Conservation Plan describes how these attributes are maintained or achieved within the foreseeable future.

Developing a Lower Columbia River White Sturgeon Conservation Plan (hereafter Conservation Plan) is an ODFW priority. The Oregon Native Fish Conservation Policy (NFCP) calls for the development of conservation plans when a species population has “high public interest or economic or other impact on the local community” (ODFW 2003). Lower Columbia River white sturgeon provide significant commercial and recreational harvest opportunities. For example, non-treaty commercial fisheries harvested 1.25 million pounds (for metric conversions see Appendix A) of white sturgeon (approximately 40,000 fish) between 2003 and 2007 (ODFW unpublished data) from the lower Columbia River. Recreational angling opportunities abound in the lower Columbia River mainstem and tributaries below Bonneville Dam. Oregon and Washington sport anglers harvested nearly 150,000 white sturgeon between 2003 and 2007 (ODFW and WDFW 2007). Currently the lower Columbia River white sturgeon population is not believed to be at risk of extinction, but this Conservation Plan will provide a conservation framework to manage this important sub-component of the species, thereby ensuring continuance of ecological and societal benefits including sustainable harvest opportunities.

Beyond being a **federal trust species**, white sturgeon in the Oregon Species Management Unit (SMU; described below) currently have no special state or federal status. However, during the 2008 update of the ODFW Sensitive Species List, white sturgeon were identified as a data gap species (ODFW 2009). In Idaho white sturgeon, including those inhabiting waters shared with Oregon, are considered a species of concern (IPC 2005), the populations in Canada and the Kootenai River are listed as endangered (USFWS 1994; Duke et al. 1999; COSEWIC 2003), and the American Fisheries Society has listed the species as a whole as endangered (Jelks et al. 2008). Despite this, white sturgeon in the lower Columbia River are not at risk of extirpation, and NatureServe, a non-profit organization whose purpose is to deliver a scientific foundation for conservation action, ranks them as “globally secure” (Jelks et al. 2008; NatureServe 2010). That being said, threats to them across their range, including Oregon, do exist. Marine mammal predation, habitat and population fragmentation, altered seasonal river discharge and **thermal regimes**, industrial and agricultural pollutants and the lack of sufficient suitable habitat for successful completion of all life-stages (i.e., spawning, rearing, feeding and migratory habitats) are some of the principal factors and threats the population segment is being subjected to. These factors, combined with a slow **maturation** rate (up to 25 years) and long life, make white sturgeon vulnerable to **recruitment** failures, over-harvest, and at put them at risk if population sizes become too small.

Consistent with the NFCP goals for native fish populations and SMUs, this Conservation Plan lays out how ODFW will manage the Lower Columbia white sturgeon population segment to:

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

The Conservation Plan builds upon the concept that locally adapted populations provide the best foundation to sustain populations of naturally produced native fish (ODFW 2003). To accomplish the aforementioned goals the Conservation Plan will, in part, attempt to synthesize pertinent white sturgeon information available in the “Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan, Volume II” (NPCC 2004), the “White Sturgeon Management

Framework Plan” (Hanson et al. 1992), and the most relevant and recent scientific literature. After this synthesis is complete, input and review of the Conservation Plan has been solicited from technical and stakeholder review teams and the public. Because so much information from this plan was taken from the subbasin and framework plans, a brief description of each follows.

The subbasin planning process was a collaborative venture involving state and federal fish and wildlife agencies, Native American tribes, and local planning and fish recovery boards. The process was guided by the Northwest Power and Conservation Council (NPCC) and funded by the Bonneville Power Administration (NPCC 2006). The Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan identifies priority restoration and protection strategies for habitat and fish and wildlife populations, including white sturgeon, in the lower Columbia River system (NPCC 2006). This plan’s intent was to help guide the implementation of the NPCC’s Columbia River Basin Fish and Wildlife Program, which aims to protect, mitigate, and enhance fish and wildlife negatively impacted by hydropower dams (NPCC 2006).

The White Sturgeon Management Framework Plan was intended to be a means for Pacific states fisheries managers to better manage white sturgeon throughout their range (Hanson et al. 1992). Specifically, it attempted to summarize across their range, white sturgeon biology and management, while providing a forum and a framework for regional planning and management sufficient to satisfy the diverse geographical needs of the white sturgeon population (Hanson et al. 1992).

This Conservation Plan will further benefit white sturgeon population management efforts in the greater Columbia River region by providing information needed to assess, monitor, and evaluate white sturgeon populations in adjacent river reaches and throughout the region. The Conservation Plan is intended to ultimately identify and aid in the prioritization of diverse sets of habitat, management, and research needs for white sturgeon, that vary considerably across the species’ range.

To achieve the Conservation Plan goals stated above, we have developed the following sections that describe:

- The biological characteristics of white sturgeon (Section 3);
- Oregon’s White Sturgeon Species Management Unit and constituent population structure (Section 4);
- Historic and current fisheries (Section 5);
- Desired status of Oregon white sturgeon residing in the lower Columbia River downstream of Bonneville Dam and along the Oregon Coast with benchmarks and metrics to measure progress made toward attaining the desired status (Section 6);
- The current status of white sturgeon in the Columbia River downstream of Bonneville Dam (Section 7);
- Existing Conservation and Management Measures for lower Columbia River white sturgeon (Section 8);
- Critical constraints, limiting factors, and threats to the health of the lower Columbia River white sturgeon population (Section 9);

- Critical unknowns and data gaps that affect managers' ability to conserve the species (Section 10);
- Specific strategies, actions and recommended research, monitoring, and evaluation necessary to conserve and manage lower Columbia River white sturgeon (Section 11);
- Conservation Plan implementation schedule and adaptive management framework (Section 12).

## Section 3. White Sturgeon Biological Characteristics

There are 25 sturgeon species worldwide and eight of these occur in North America (Bemis and Kynard 1997). White sturgeon are the largest of the eight, and are the largest freshwater or **diadromous** fish in North America (Page and Burr 1991), able to reach lengths of 20 ft. (Scott and Crossman 1973) and weights of 1,800 lbs. (Hart 1973). They have a cartilaginous skeleton, a persistent notochord, and lack scales (Scott and Crossman 1973). However, white sturgeon have patches of small **denticles** and five rows of larger bony plates called scutes (Scott and Crossman 1973). The arrangement and number of scutes on sturgeons is used to distinguish white sturgeon (11 – 14 dorsal, 36 – 48 lateral, and 9 – 12 ventral scutes) from other sturgeon species (Schreiber 1959; Scott and Crossman 1973; Moyle 1976; North et al. 2002).

White sturgeon are **freshwater amphidromous**, meaning they spawn in freshwater but regularly move between fresh and saltwater to feed (Scott and Crossman 1973; Bemis and Kynard 1997; Wydoski and Whitney 2003). In **riverine** environments white sturgeon seem to prefer free flowing stretches (Bajkov 1951; Haynes et al. 1978), though they are known to inhabit stiller habitats as well (Haynes et al. 1978). In the lower Columbia River below Bonneville Dam, immature 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).

White sturgeon are found in the ocean from northern Baja, Mexico to the Aleutian Islands in Alaska (Eschmeyer et al. 1983; Rosales-Casian and Ruz-Cruz 2005) and in large rivers along the Pacific Coast between Monterey, California and Alaska (Scott and Crossman 1973; Page and Burr 1991). White sturgeon are found in many coastal rivers, but their reproduction appears to be limited to the Sacramento-San Joaquin, Columbia, and Fraser river systems (Hanson et al. 1992). These basins are the source of white sturgeon observed in coastal rivers, estuaries, and the ocean (Hanson et al. 1992).

White sturgeon are genetically distinctive. Unlike humans who have 46 **chromosomes** (DeGrouchy 1987) and are diploid, that is an organism that has two sets of identical chromosomes, or Chinook salmon *Oncorhynchus tshawytscha*, which have 68 chromosomes (Simon 1963) and are tetraploid (Allendorf and Thorgaard 1984), that is organisms with four sets of identical chromosomes, white sturgeon possess ~250 chromosomes and are believed to be **octoploid**, that is, an organism with eight complete sets of identical chromosomes (Birstein

2005; Vasil'ev 2009; Drauch Schreier et al. *in press*). This may not be set in stone, however, as white sturgeon inheritance appears to have some variability associated with it. 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).

Although they are closely related, there appear to be small, significant genetic differences among white sturgeon populations from the Sacramento, Columbia, and Fraser river systems (Bartley et al. 1985, Brown et al. 1992, Anders and Powell 2002). White sturgeon are capable of long distance migrations through both fresh and salt water, but evidence to support high levels of contemporary **gene flow** is limited. This conclusion is consistent with recaptures of marked white sturgeon that indicate movement between river systems is uncommon (Chadwick 1959; Galbreath 1985; DeVore and Grimes 1993; Watts 2006; Welch et al. 2006), and from a recent investigation of genetic variability of **juvenile white sturgeon** in the lower Columbia River (Drauch and May 2009).

Early life history terminology used in this document, e.g., **embryo**, **free swimming embryo**, and larva, were adapted from Balon (1984) and is similar to that used by van der Leeuw (2006). Embryos begin at fertilization, spawning and hence fertilization typically occur in the spring when water temperatures are 50 – 64 °F, and end at hatch. Free swimming embryos begin at hatch and end when white sturgeon begin **exogenous feeding**. The larval stage begins at exogenous feeding and ends when all fins and organs are fully developed (Figure 1).

Contradictory information exists on the transition from one early life history stage to another in white sturgeon. One hypothesis states that newly hatched white sturgeon exhibit three distinct phases between hatch and **metamorphosis**, each lasting approximately six days (Figure 1; Brannon et al. 1986). The first phase, dispersal, occurs immediately after hatching when free swimming embryos **swim up** into the water column (Brannon et al. 1987; Conte et al. 1988). In the lower Columbia River dispersing embryos have been collected at depths of 13 – 190 ft. and over a variety of substrates (Parsley et al. 1993). After dispersal, free swimming embryos sink to the bottom and burrow themselves in gravels during their hiding phase (Conte et al. 1988). White sturgeon **larvae** begin active feeding approximately 12 days after initial dispersal into the water column (Buddington and Christofferson 1985; Conte et al. 1988). The larvae complete their metamorphosis in approximately 20 days (Buddington and Christofferson 1985).

Emerging evidence suggests that the timing and behavior during these transitions may differ by geographic region. 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. 2008). 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). A weak dispersal behavior lasting only a few hours to a few days was noted in newly hatched free swimming embryos, followed by hiding and active external feeding through larval stages and a longer, stronger dispersal post-metamorphosis (Kynard and Parker 2005).



**Figure 1.** Depiction of the white sturgeon life cycle including embryo, free swimming embryo, larva, age-0, juvenile, sub-adult and adult life stages. Male white sturgeon mature earlier than female white sturgeon. Males may be sexually mature between age-10 and 15 (~ 54 inches FL) females mature between age-15 and 25 (~ 66 inches FL).

Life history terminology used in this document, beyond the larval stage, is as follows. Age-0 begins after 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 38 inches fork length (FL); McEnroe and Cech 1985; ODFW, unpublished data). **Sub-adult white sturgeon** can enter estuarine and marine environments but are not sexually mature. **Adult white sturgeon** are sexually mature. Maturity in white sturgeon is more an artifact of size than age (Conte et al. 1988), and both can vary widely (IPC 2005). In the Columbia River, most male white sturgeon reach sexual maturity at approximately 54 inches (UCWSRI 2002) FL, though some may become mature at smaller sizes (Galbreath 1985; Hanson et al. 1992). Females mature later, at about 65 inches FL, often taking 15 to 35 years to reach maturity (Bajkov 1949; Scott and Crossman 1973; Welch and Beamesderfer 1993; IPC 2005).

In the lower Columbia River reservoirs upstream of Bonneville Dam, white sturgeon exhibit rapid first year growth reaching sizes up to 10 inches FL by the end of the first growing season (Chapman and Kern 2005). After the first year, annual growth decreases continuously until fish reach approximately 33 inches FL (ODFW unpublished data). For the size 33 – 48 inches, annual growth increases, again followed by a decrease in annual growth rate for fish larger than 48 inches FL (ODFW unpublished data).

White sturgeon can be characterized as “periodic reproductive strategists” (Winemiller and Dailey 2002). Periodic strategist species typically live for long periods of time, and experience low mortality after the juvenile stages. These fish typically mature late in life, are **iteroparous**, that is spawn many times over the course of their life, and produce many offspring. The periodic strategy is believed to have evolved in response to highly variable environments, in which mortality of young may be variable and very high. In these environments, successful reproduction may depend on specific cues or conditions, which may be relatively rare events. The long life and high **fecundity** of periodic strategists are adapted to take advantage of less common productive conditions when they arise, ensuring long-term persistence of the population. Once reaching maturity, female white sturgeon can produce between 100,000 to 7 million eggs each spawning cycle (Bajkov 1949; Scott and Crossman 1973), and may spawn several times over the course of their life (Scott and Crossman 1973; Bemis and Kynard 1997; Webb and Kappenman 2008). **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), though spawning events for both sexes may occur as frequently as every two years (Webb and Kappenman 2008), or as long as 11 years between events (Semakula and Larkin 1968). These spawning cycles exceeding one year between spawning events are relatively rare even among periodic spawners and may be referred to as **punctuated iteroparity** (Winemiller and Dailey 2002). Most periodic fishes are physiologically capable of spawning at least annually, but may do so only when conditions are favorable, this is not the case with white sturgeon. Under natural conditions female white sturgeon are only physiologically capable of spawning about once every two to five years (Webb and Kappenman 2009). Additionally, since the development cycle of white sturgeon eggs is protracted, females are not able to choose to spawn in good years unless the timing coincides with the development cycle already underway. Thus, rather than delaying spawning until favorable conditions occur, as some periodic fishes may, white sturgeon have evolved to spawn on a multi-annual basis regardless of conditions. Variability in productivity is typically reflected during the fertilization, hatching, or early rearing stages of the life cycle, rather than in fecundity or maturation. While female white sturgeon are unable to accelerate the maturation process in favorable years, they are susceptible to reduced or delayed maturation, including re-absorption of developing eggs in unfavorable years. This **follicular atresia**, which in some fish species allows females to recover a portion of the energetic investment in spawning (van Damme et al. 2009), means the postponing of the spawning event in favor of better conditions, but also re-starts the multi-year maturation cycle.

White sturgeon are **broadcast spawners**, releasing their eggs and sperm into the water column over boulder and cobble substrates where fertilization occurs (Hanson et al. 1992; Parsley et al. 1993). White sturgeon generally spawn in the spring when the water temperatures are between 50 – 64 °F (Hanson et al. 1992; Parsley et al. 1993; Chapman and Jones 2010a) and turbidities are high (Perrin et al. 2003). White sturgeon spawn near the river bottom, in areas where water velocities average 3.1 miles per hour (mph) and range between 1.1 and 5.6 mph (Parsley et al. 1993; Parsley and Beckman 1994) and with high **hydraulic complexity** (Perrin et al. 2003).

Average spawning depths can exceed 20 ft. (Parsley et al 1993; Chapman and Jones 2010a). In the lower Columbia River most new eggs are found on cobble or boulder substrate and at depths of 13 – 89 ft. (Parsley et al. 1993). Optimal incubation temperature for white sturgeon eggs is 57 °F (Wang et al. 1985), and incubation generally lasts 7 to 14 days (Wang et al. 1985; Conte et al. 1988) depending on water temperature.

During early life stages white sturgeon in the lower Columbia River use a variety of rearing habitats. Age-0 white sturgeon in the lower Columbia River prefer deep (29 – 125 feet), 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% of age-0 white sturgeon > 6 inches FL downstream of Bonneville Dam were encountered over sand, and that they seemed to prefer the main river channel, a location that would have minimized the risk of stranding even in naturally free flowing rivers. Juvenile and sub-adult white sturgeon use a wide variety of depths ( 6 – 131 ft.; Parsley et al. 1993; Parsley et al 2008) and juvenile white sturgeon prefer low velocity areas over sandy substrates (Parsley et al. 2002). Though juvenile and sub-adult white sturgeon use a wide variety of depths, they appear to exhibit different preferences based on the diel period. Parsley et al. (2008) observed the average daylight depth for juvenile and sub-adult white sturgeon to be 69 ft. and average night depth to be 49 ft. Though fish observed by Parsley et al. (2008) exhibited this diurnal/nocturnal migration, depths used by individual fish were highly variable, with some fish occupying depths < 16 ft. and others staying > 33 ft. 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 sandy substrate habitats with moderate riverbed roughness and slope (Hatten and Parsley 2009).

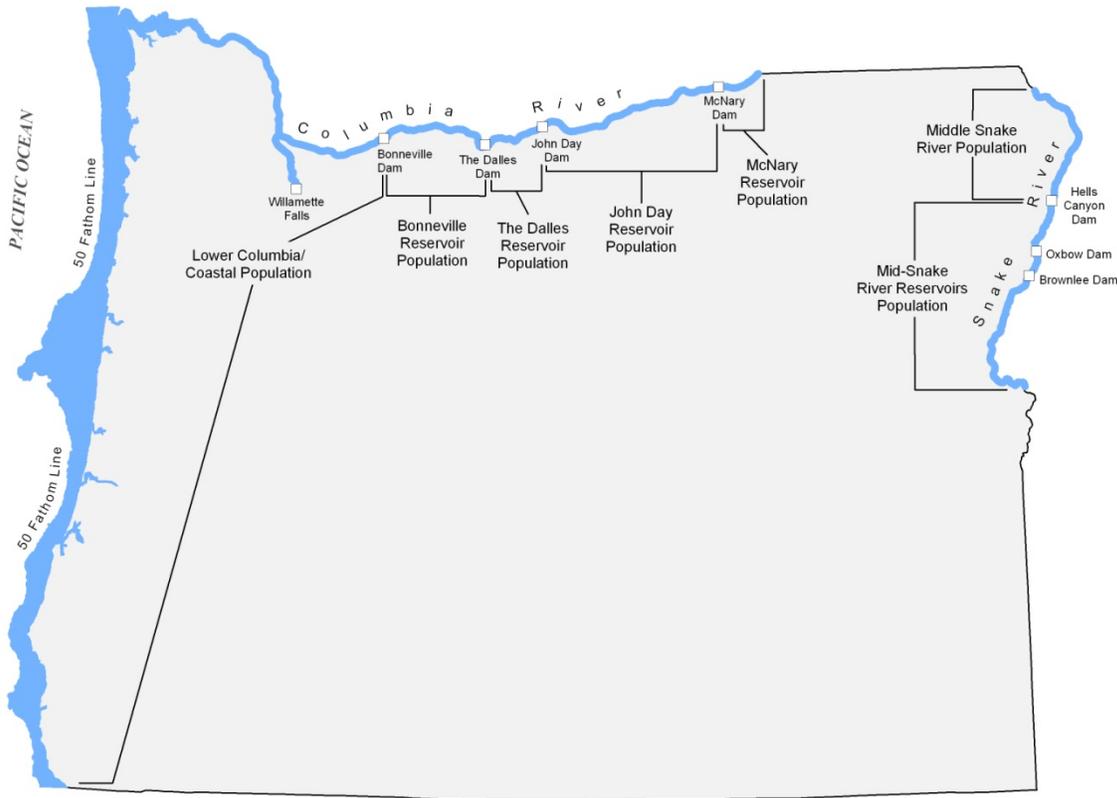
## Section 4. Species Management Unit Structure

The NFCP requires the identification of SMUs for native species of interest or concern (ODFW 2003). An SMU is defined as a group of populations from a common geographic area with similar genetic and life history characteristics. It also represents the lowest level, in theory, at which native fish are managed in Oregon (ODFW 2003). Conceptually, SMUs are designed similarly to the Evolutionarily Significant Units (ESUs) proposed by Ryder (1986). The ESU, which is used by the National Marine Fisheries Service (NMFS) when determining **Endangered Species Act** (ESA) status of Pacific salmon stocks, is the theoretical foundation for interpreting the phrase **distinct population segment** (DPS), when considering the ESA status of other **vertebrate** fish and wildlife populations (U.S. Department of Interior and U.S. Department of Commerce 1996). Both, the U.S. Fish and Wildlife Service and NMFS use the term DPS. The SMU delineations in Oregon include both ESA-listed and unlisted species and populations.

### 4.1 Oregon White Sturgeon SMU

Prior to the construction of the Federal Columbia River Power System (FCRPS) white sturgeon are assumed to have ranged freely throughout the Columbia River System upstream to Windermere Lake on the Columbia River (UCWSRI 2002), Bonnington Falls on the Kootenai River (Paragamian et al. 2005) and Shoshone Falls on the Snake River (IPC 2005). Preliminary **mitochondrial** genetic investigations by Setter and Brannon (1992) and Anders et al. (2000)

suggested a single genetically **homogeneous** white sturgeon population within Oregon waters. Because of this, all Oregon white sturgeon population segments have been combined and are represented by one SMU, despite being managed separately in more discrete units defined by geographic markers (Figure 2; ODFW 2005a; ODFW 2005b). However, more recent nuclear genetic work by Rodzen et al. (2004) suggests that the white sturgeon in the Snake River above Hells Canyon Dam may be genetically distinct from lower Columbia River white sturgeon, with those population segments inhabiting the reservoirs as intermediate (Rodzen et al. 2004). Furthermore, the construction of the FCRPS resulted in the fragmentation of Oregon white



**Figure 2.** Map of Oregon white sturgeon species management unit (SMU)

sturgeon into seven functionally discrete population segments (Table 1). These population segments are grouped based upon similarities in biological characteristics and in applied management strategies among individual river reaches and impounded water bodies within the SMU.

**Table 1.** Population list for the Oregon white sturgeon SMU

<b>Population</b>	<b>Description</b>
Lower Columbia/Coastal	Columbia River downstream of Bonneville Dam, Willamette River downstream of Willamette Falls, Coastal estuaries and rivers, Oregon coast inside 50 fathom line
Bonneville Reservoir	Bonneville Dam to The Dalles Dam
The Dalles Reservoir	The Dalles Dam to John Day Dam
John Day Reservoir	John Day Dam to McNary Dam
McNary Reservoir	McNary Dam to Priest Rapids Dam (Columbia River) and Ice Harbor Dam (Snake River)
Middle Snake River	Unimpounded Snake River from the confluence of the Salmon River to Hells Canyon Dam
Middle-Snake River Reservoirs	Hells Canyon, Oxbow, and Brownlee reservoirs

These population segments may not represent a historical **metapopulation**; however, they do represent groups that, due to hydropower development, presently function separately with restricted interactive opportunities. Those interactive opportunities that do occur are primarily downstream in nature through **entrainment** (Coutant and Whitney 2000; Parsley et al. 2007) and other passage routes including spill ways, fish ladders, and navigation locks (Parsley et al. 2007). Upstream movements, though possible at some dams, are uncommon throughout the FCRPS (North et al. 1993; Parsley et al. 2007).

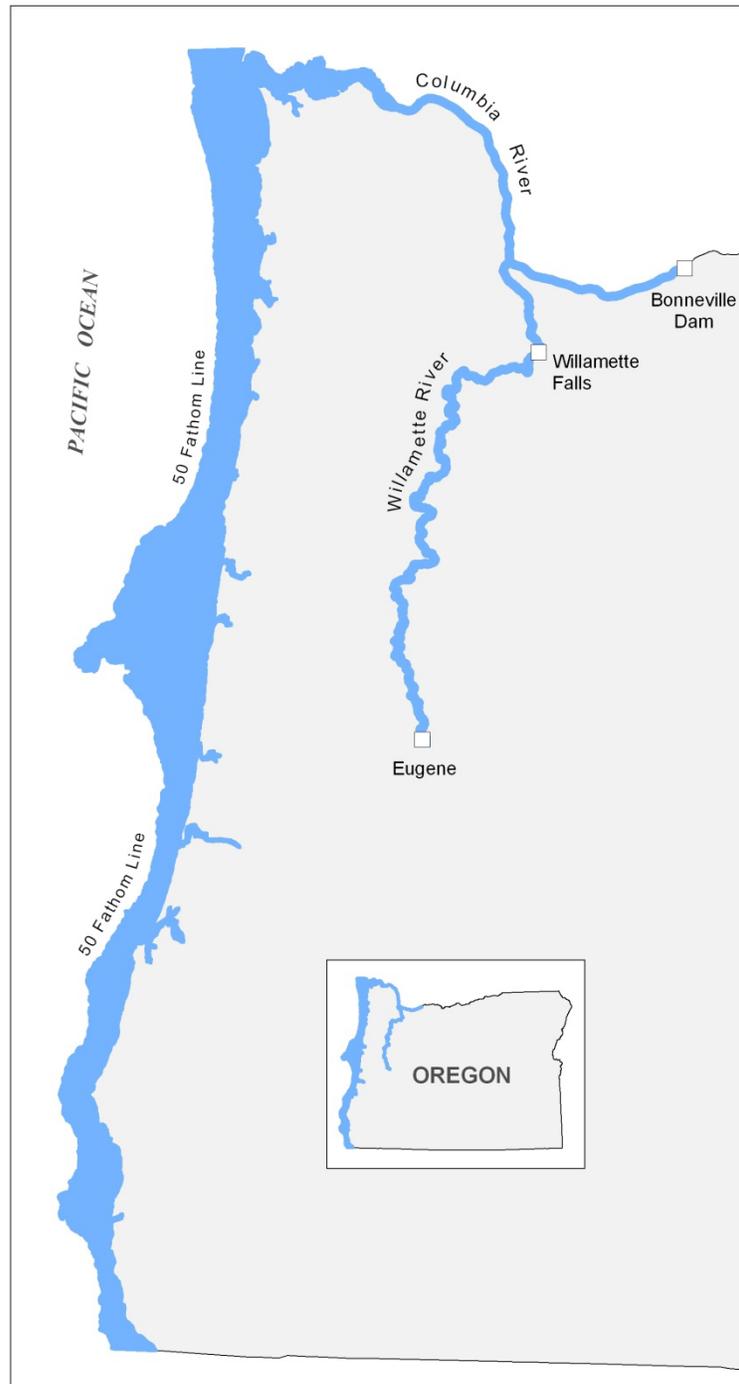
#### **4.2 Lower Columbia River White Sturgeon Population Segment**

Although Oregon white sturgeon are represented by a single SMU, the 2005 Oregon Native Fish Status Report (ODFW 2005b) suggests that a finer classification "...may be appropriate in the future." Additionally, protections under the federal ESA can be extended to any DPS of any species of vertebrate fish or wildlife which interbreeds when mature (Pennock and Dimmick 1997). Though the populations within the current SMU may have been genetically homogeneous in the distant past, there is evidence of geographic isolation, both natural and human-induced, altering the genetic structure of the Snake River (Setter and Brannon 1992; Rodzen et al. 2004) population segment and the Kootenai River population (Setter and Brannon 1992; Anders and Powell 2002; Rodzen et al. 2004). The lower Columbia River population segment is the most abundant and productive within the current SMU and the Columbia Basin as a whole (Cochnauer et al. 1985; Beamesderfer et al. 1995; DeVore et al. 1995). Due to the construction of the FCRPS, white sturgeon residing downstream of Bonneville Dam are the only population segment in the once basin-wide meta-population that can still access ocean and estuarine environments, therefore able to maintain an amphidromous life history strategy, and have access to interchange pathways between Sacramento and Fraser River populations (Hanson et al. 1992).

Differences in the biology and status between white sturgeon population segments downstream and upstream of Bonneville Dam necessitate widely different management approaches. For the purpose of this Conservation Plan, we focus on the population segment downstream of Bonneville Dam and within the current Oregon White Sturgeon SMU, including coastal waters. It should be noted that based on the best available information (ODFW, unpublished data) the majority of white sturgeon downstream of Bonneville Dam inhabit the lower Columbia River proper. However, white sturgeon are also present in the Willamette River (mostly downstream

of Willamette Falls, Oregon). Furthermore, white sturgeon are found in coastal rivers, estuaries, bays, and marine waters inside the 50 fathom (91 m; 300 feet) line of the Oregon coast Figure 3). They exhibit free interchange between these coastal and marine habitats and the lower Columbia River. Although there are historic reports of white sturgeon in the mainstem Willamette River as far upstream as Eugene, Oregon (Dimick and Merryfield 1945), and of historic floods to a depth of nearly 400 ft. (Allen et al. 2009) covering the entire Willamette Valley during the ice age Missoula Floods, uncertainty exists as to whether white sturgeon occupied this area prior to European settlement. White sturgeon habitat use in the Willamette River above Willamette Falls is poorly understood. From 1989 – 2003, this area received periodic supplementation of juvenile white sturgeon produced from wild **broodstock** and reared in a private hatchery (ODFW, unpublished data). White sturgeon in this area are currently believed to be largely the result of the now discontinued hatchery stocking practices. The current status of these fish is largely unknown, though distribution appears to cover the extent of the mainstem Willamette River from the confluence with the Columbia River upstream to the confluence of the Coast and Middle forks of the Willamette River near the city of Eugene, Oregon, approximately river mile (RM) 186 (Figure 3). Regardless of the uncertainty surrounding the origins of white sturgeon inhabiting this reach and its assumed low white sturgeon abundance compared to the mainstem lower Columbia River, the reach is given consideration within this Conservation Plan.

At this time, we believe it is appropriate to prepare separate conservation plans for those Columbia and Snake River white sturgeon population segments upstream of Bonneville Dam in the future and following the completion of this lower Columbia River Conservation Plan. As stated above, our primary focus here are white sturgeon inhabiting the mainstem lower Columbia River downstream of Bonneville Dam with consideration given to adjacent Oregon freshwater habitats downstream of Bonneville Dam and the previously mentioned Oregon coastal and marine habitats.

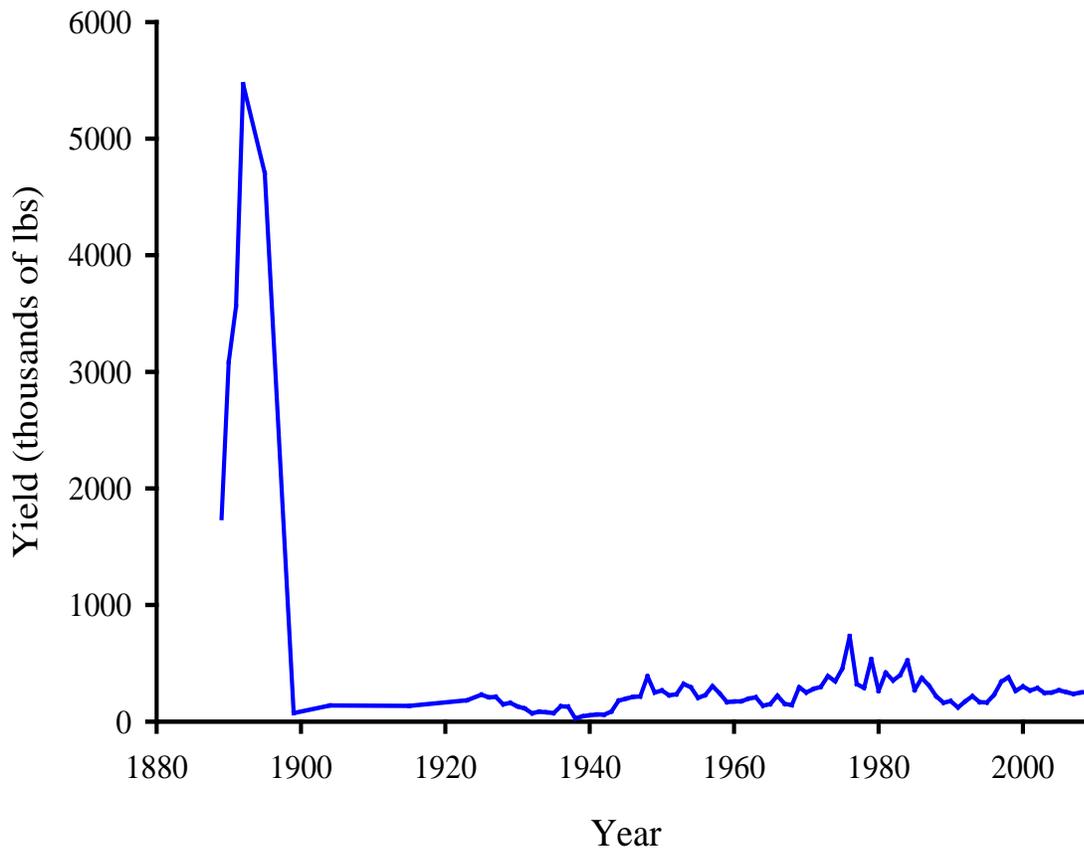


**Figure 3.** Map of the lower Columbia River population of white sturgeon including the Willamette River to Eugene, Oregon, and Oregon coastal waters inside of the 50 fathom line.

## Section 5. Historic and Current Fisheries

Commercial use of white sturgeon in the lower Columbia River has been documented since the middle of the 19<sup>th</sup> century, with the first reported commercial sales being made to European explorers by Native American tribes along the Columbia River (Craig and Hacker 1940). Between 1870 and 1890, settlers moving into the area began to develop commercial gill net, trap, and fish wheel fisheries for Pacific salmon species *Oncorhynchus spp.*. White sturgeon captured in these fisheries were considered safety hazards and those caught, regardless of size, were frequently killed 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 white sturgeon fishery was established in the lower Columbia River, second in value only to the salmon fishery (Craig and Hacker 1940). The Columbia River white sturgeon commercial fishery peaked in 1892, with a harvest of nearly 5.5 million pounds of white sturgeon (Figure 4) in the absence of any harvest regulations. Sturgeon abundance dropped dramatically between 1893 and 1895 (Craig and Hacker 1940); in 1899 a minimum size limit of 4 ft. total length (TL) and a four-month fishing season were imposed and setlines using numerous un-baited hooks to snag fish as they swim by, were banned (Oregon Revised Statute 509.235; Table 2). Despite, or perhaps because of these regulatory changes, the fishery collapsed and less than 75,000 pounds were harvested in 1899 (Craig and Hacker 1940).

For the next 70 years the white sturgeon commercial fishery remained functionally non-existent and only incidental to salmon fisheries (Craig and Hacker 1940; Hanson et al. 1992; ODFW/WDFW 2009a). In 1950, a 6 ft. TL maximum harvestable size regulation was established for sport and commercial fisheries to protect sexually mature white sturgeon. This management action was most likely the catalyst in rebuilding white sturgeon stocks in the Columbia River. With stocks partially recovered, an annual targeted white sturgeon commercial fishery was reinstated in 1974. This fishery was reopened in an effort to partially offset the economic hardships to commercial salmon fishers from declining salmon runs (Hanson et al. 1992). The white sturgeon fishery included directed catch from baited setlines and incidentally caught fish in salmon gill nets (Galbreath 1985). However, in 1982, the State of Washington passed a law requiring the use of setlines below Bonneville Dam to be phased out. By 1985, large mesh ( $\geq 9$  inch) gill nets were established as the primary gear for white sturgeon (Galbreath 1985; Hanson et al. 1992).



**Figure 4.** Annual commercial yield in pounds of lower Columbia River white sturgeon, 1889 – 2009.

Prior to 1970, recreational angling for white sturgeon was limited and focused primarily in the approximately 15 miles immediately downstream of Bonneville Dam. Furthermore, 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 trout *Oncorhynchus mykiss* stocks, and during this time the white sturgeon population appeared to be healthy and increasing in abundance. 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 1980s, 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 since 1989 (Tables 2 and 3; ODFW/WDFW 2007).

**Table 2.** History of Commercial Sturgeon Regulations in the Lower Columbia River (ODFW/WDFW 2009a).

Year	Size Limits (TL)	Gear and Other Restrictions
1899	48 inch minimum.	Snagging setlines prohibited
1899-1908	“	Sturgeon sales closed
1909	“	Sales allowed during salmon seasons
1938	“	Beacon Rock-Bonneville Dam sanctuary established
1950	48 – 72 inches	
1968	“	Zone 6 set as exclusive treaty Indian fishery
1975-1982	“	Target setline seasons allowed
1983-1985	“	Setline seasons phased out
1983-1988	“	Target gill-net seasons (in-lieu of setlines)
1989	“	Target gill-net seasons eliminated
1990-1992	“	9 inch max. mesh restriction in late fall salmon seasons
1991	“	WA only – 2 lbs. lead/fathom of leadline
1992	60 inch maximum (WA only)	Max. length restrictions for fall seasons only
1993	48 – 66 inches	9 inch max. mesh adopted as permanent rule, sturgeon sales closed during last 2 weeks of fall salmon season (6,000 catch expectation for 1993 reached)
1994	“	Harvest ceiling of 6,000, sturgeon sales closed after first day of fall salmon season
1995-1996	“	Harvest ceiling of 8,000, no more than 6,800 (85%) may be taken in fall salmon fisheries
1997-1998	48 – 60 inch white sturgeon and 48 – 66 inch green sturgeon	Joint Accord adopted - annual recreational and commercial catch guidelines formalized; 20% (13,460 white sturgeon) of harvest guideline allocated to the commercial fishery; White sturgeon gillnet target seasons allowed; Green sturgeon target seasons not allowed; 9.75 inch max. mesh adopted as permanent rule
1999-2000	“	10,000 annual white sturgeon harvest guideline
2001	“	9,100 annual white sturgeon harvest guideline
2002	“	9,800 annual white sturgeon harvest guideline
2003	48 – 60 inch all sturgeons	8,000 annual white sturgeon harvest guideline
2004	“	8,000 annual white sturgeon harvest guideline
2005	“	8,200 annual white sturgeon harvest guideline
2006	“	8,000 annual white sturgeon harvest guideline; green sturgeon retention and sales prohibited effective July 7 and adopted as permanent rule.
2007	“	7,850 annual white sturgeon harvest guideline
2008	“	7,930 annual white sturgeon harvest guideline
2009	43 – 54 inch FL all sturgeons	8,000 annual white sturgeon harvest guideline
2010	“	4,800 annual white sturgeon harvest guideline

**Table 3.** History of sturgeon regulations for the lower Columbia River (LCR) sport fishery (ODFW/WDFW 2009a).

Year	Daily Bag Limit	Annual Bag Limit	Size Restrictions	Other Regulations
Pre-1940	None	None	None	None
1940		"	"	Only 3 < 4 ft.
1942	5 Fish	"	"	3 < 4 ft. 2 ≥ 4 ft.
1950	"	"	30 in. - 72 in.	"
1951	3 Fish	"	"	"
1957	"	"	"	Head and tail intact in the field.
1958	"	"	36 in. - 72 in.	"
1986	2 Fish	OR-30	"	<u>OR</u> --required sturgeon tag; <u>WA</u> --no gaffing.
		OR-30, WA-		<u>WA</u> --required sturgeon tag. New minimum size limit effective April 1.
1989	"	15	40 in. - 72 in.	
1990	"	15	"	Single-point barbless hooks required. <u>OR</u> --no gaffing.
1991	1 and 1	"	"	Daily limit changed to one fish 40 - <48" and one fish 48-72".
1992	"	"	"	<u>WA</u> —60 in. max. effective 4/16/1992- 4/15/1993. <u>WA</u> --Beacon Rock to Bonneville Dam sturgeon sanctuary (boat and bank) 4/16 – 6/15/1992.
1994	"	10	42 in. - 66 in.	Daily limit changed to one fish 42-<48" and one fish 48-66".
1995	"	"	"	LCR closed to retention 9/1 – 12/31.
1996	1 Fish	"	"	One 42-66" fish daily bag limit effective 4/1. Closed to boat angling from Beacon Rock to Bonneville Dam 5/1 – 6/30.
1997	"	"	42 in. - 60 in.	80% allocation of 67,300 annual harvest guideline to sport fishery (53,840).
1999	"	"	"	Harvest guideline to 50,000 (40,000 sport). U.S.A.C.E. starts Bonneville Boat Restricted Zone from Robins Is. to Hamilton Is. boat ramp.
2000	"	"	"	Retention closed below Wauna powerlines 4/1-30. Beacon Rock to Bonneville boat angling closure extended through 7/15. Annual limit 10 fish even if licensed in both states.
2001	"	"	"	LCR closed to retention 8/1 - 9/30.
2002	"	"	"	LCR closed to retention on Sundays and Mondays during 3/3 - 5/13 and seven days per week during 7/25 – 11/22.
2003	"	"	"	32,000 harvest guideline, 40% above Wauna - 60% below Wauna. Retention allowed above Wauna 1/1 – 3/23 and 7/1 – 10/31, and below Wauna 1/1 – 6/27.
2004	1 Fish	5	42 in. - 60 in. 45 in. below Wauna 5/15 – 7/3	28,800 harvest guideline, 12,800 above Wauna – 16,000 below Wauna. Retention allowed above Wauna 1/1 - 31, then Thursday - Saturday 2/1 – 7/31 and 10/1 – 12/31. Retention allowed below Wauna 1/1 – 4/30 under permanent rules, then 5/15 – 7/3 with a 45 in. minimum size limit. Closed to boat and bank angling from Beacon Rock to Bonneville Dam 5/1 – 7/31.
2005	"	"	42 in. – 60 in. 45 in. below Wauna 5/14 – 7/1- and 7/15 – 8/15	30,600 harvest guideline, 12,800 above Wauna – 17,800 below Wauna. Retention allowed above Wauna Thursday – Saturday 1/1 – 7/31 and 10/1 – 12/31. Retention allowed below Wauna 1/1 – 4/30 under permanent rules, then 5/14 – 7/10 and 7/15 – 8/15 with a 45 in. minimum size limit.

**Table 3 (continued).** History of sturgeon regulations for the lower Columbia River sport fishery.

Year	Daily Bag Limit	Annual Bag Limit	Size Restrictions	Other Regulations
2006	"	"	42 in. – 60 in. 45 in. below Wauna 5/13 – 7/4	28,800 harvest guideline split 12,800 above Wauna – 16,000 below Wauna. Retention allowed above Wauna Thursday – Saturday 1/1 – 7/31 and 10/1 – 12/31. Retention allowed below Wauna 1/1 – 4/30 under permanent rules, then 5/13 – 7/4 with a 45 in. minimum size limit. Closed to boat and bank angling from Navigation Marker 85 to Bonneville Dam 5/1 – 7/31.
2007	"	"	42 in. – 60 in. 45 in. below Wauna 5/12 – 7/4	30,600 harvest guideline split 14,300 above Wauna and 16,300 below Wauna. Retention allowed above Wauna Thursday – Saturday 1/1 – 31 and Thursday – Sunday 2/1 – 7/31; seven days per week 8/18 – 12/31. Sturgeon retention allowed below Wauna 1/1 – 4/30 under permanent rules then 5/12 – 7/4 with a 45 in. min. size limit. No green sturgeon retention.
2008	"	"	42 in – 60 in. 45 in below Wauna 5/10 – 7/26	Retention allowed above Wauna four days per week (Thur-Sun.) 1/1 12/31. Sturgeon retention allowed below Wauna 1/1 – 4/30 under permanent rules then 5/10 – 6/24, 7/10 – 7/12, 7/17 – 7/19, and 7/26 with 45 in. minimum size limit. Retention of green sturgeon prohibited.
2009	"	"	38 in. – 54 in. FL 41 in. FL below Wauna 5/9 – 7/25	Fork length measurement. Retention allowed above Wauna three days per week (Thur.-Sat.) 1/1 – 7/31 and 10/1 – 12/31. Retention allowed below Wauna 1/1 – 4/30 under permanent rules then 5/9 – 6/28, 7/2 – 7/5, 7/10 – 7/12, 7/17 – 7/19, and 7/24 – 7/26 with a 41 in. minimum size (FL) limit. Retention of green sturgeon prohibited.
2010	"	"	38 in. – 54 in. FL 41 in. FL below Wauna 5/22 – 8/1	19,200 harvest guideline split 7,700 above Wauna (including Willamette River 2,865) and 11,500 below Wauna. Retention allowed above Wauna Thursday – Saturday 1/1 – 7/31 and 10/1 – 12/31; closed inside Sand Island (RM 131, near Rooster Rock) 4/29 – 7/31. All sturgeon angling closed 5/1 – 8/31 from Skamania Island (RM 135) to Bonneville Dam. Retention allowed below Wauna 1/1 – 4/30 under permanent rules then 5/22 – 7/11 and 7/15 – 8/1. Retention of green sturgeon prohibited.

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 (typically) 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 near-term population trend indices.

Also adopted in 1996 was a seasonal no-fishing sanctuary 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 that targeted large fish. This area was already established as a commercial fishing sanctuary. The recreational closure initially included the months of May and June, but in 2000 was extended through mid-July to provide additional protection to adult white sturgeon. The 2006 Accord extended the sanctuary an additional 1.5

miles downstream to U. S. Coast Guard Navigation Marker 85. In 2010 it was extended another ~ 5 miles downstream to Skamania Island, and expanded temporally until August 31 (Table 3). Furthermore, the 2006, 2010, and 2011 Accords recommend basic monitoring of increasing predation on white sturgeon by marine mammals.

Beginning in 1997, the white sturgeon harvestable guideline has allocated 80% to recreational fisheries and 20% to commercial fisheries and set at an overall number of fish believed to optimize conservation objectives and economic benefits (ODFW/WDFW 2007). The proportional allocation for recreational and commercial fisheries has not changed since 1997; however, the overall guidelines were adjusted through time and were managed at a combined total of 36,800 white sturgeon annually from 2006 to 2009 (Table 4). If the harvest is more or less than the guideline in one of the typically three year period, the guideline may be decreased or increased the following year to make up the difference (ODFW/WDFW 2009b).

**Table 4.** Summary of lower Columbia and Willamette River recreational and commercial catches compared to approved guidelines (ODFW/WDFW 2009a).

Year	Recreational		Commercial	
	Harvest <sup>1</sup>	Guideline	Harvest	Guideline
1997	38,200	53,840	12,800	13,460
1998	41,600	53,840	13,900	13,460
1999	39,800	40,000	9,500	10,000
2000	40,500	40,000	10,870	10,000
2001	41,200	39,500	9,310	9,100
2002	38,300	38,300	9,620	9,800
2003	32,300 <sup>2</sup>	32,000	7,950	8,000
2004	28,100 <sup>2</sup>	28,800	7,866	8,000
2005	30,900 <sup>2</sup>	30,600	8,152	8,200
2006	26,400 <sup>2</sup>	28,800	8,312	8,000
2007	34,400 <sup>2</sup>	30,126	7,761	7,850
2008	27,400 <sup>2</sup>	25,530	7,859	7,927
2009 <sup>3</sup>	23,300 <sup>2</sup>	26,959	7,737	8,000

<sup>1</sup>Harvest numbers have been rounded to the nearest 100.

<sup>2</sup>Catch estimates for 2003 – 2009 include estimate Willamette River harvest in excess of the adjusted 1986-1996 baseline (n=1,225; ODFW/WDFW 2009a).

<sup>3</sup>2009 harvest numbers are preliminary

The number of anglers participating in the 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, the targeted oversize fishery remains popular in the 17 river miles immediately downstream of Bonneville Dam, with an average of 8,200 angler trips occurring in this area between 2006 and 2008 (ODFW, unpublished data).

Fisheries outside of the Columbia River are low in comparison to in-river catches. Harvest in recreational fisheries in the Willamette River above Willamette Falls, coastal tributaries, and in the ocean average three percent of the combined lower Columbia River guideline (Table 5); the ocean commercial yield for Oregon fisheries averages less than 55 lbs. per year since 2000.

White sturgeon harvest in Washington recreational fisheries outside of the Columbia River are also low in comparison to in-river guidelines, averaging 1,050 fish between 2001 and 2009 (Table 6).

**Table 5.** Recreational harvest of white sturgeon in the Willamette River above the Willamette Falls, Oregon coastal tributaries, and ocean catch.

Year	Willamette	Coastal Tributaries	Ocean
2000	124	1433	172
2001	165	996	150
2002	195	812	107
2003	101	871	160
2004	108	664	102
2005	84	745	69
2006	87	878	108
2007	280	1462	321
2008	223	703	83
2009	165	818	62

**Table 6.** Recreational harvest of white sturgeon in Washington coastal estuaries, bays, and rivers, and in Puget Sound<sup>1</sup>.

Year	Willapa Bay & Tributaries	Grays Harbor & Tributaries	Washington Coastal Rivers	Puget Sound
2001	575	582	16	442
2002	274	412	0	387
2003	625	570	36	276
2004	384	324	6	150
2005	478	207	0	140
2006	363	268	0	225
2007	94	187	0	409
2008	401	47	0	505
2009 <sup>2</sup>	337	86	0	655

<sup>1</sup> Estimates are expanded from catch record card reporting

<sup>2</sup> Preliminary

## Section 6. Desired Lower Columbia River White Sturgeon Population Segment Status

The goal of this Conservation Plan is to avoid any substantial reductions in the lower Columbia River white sturgeon population segment, maintain a naturally reproducing population segment in the lower Columbia River, that makes full use of natural habitats, providing ecological,

economic, and cultural benefits to Oregon residents, and provide sustainable commercial and recreational fishing opportunities. Lower Columbia River white sturgeon are important to Oregon and the region as a whole. Ensuring persistence and genetic diversity of the species and its ecological niche, now and for future generations, is necessary to maintain the social, cultural and economic benefits that this population currently provides.

The lower Columbia River white sturgeon population segment is not believed to be at risk of extirpation. However, preserving it and building it into a population segment that is both healthy and capable of sustaining robust, meaningful harvest opportunities is essential. To help identify progress towards Conservation Plan objectives we follow the NFCP guidance of having measurable biological criteria (benchmarks) for the **desired** and **conservation status** of the population segment. We define achieving the healthy and harvestable goal of this Conservation Plan as reaching the desired status for all biological attributes. Thresholds for conservation status represent a lower level of biological health. However, they should not be viewed as the lower end of an otherwise healthy population, but rather as early warning indicators below which conservation actions will be warranted and a level that must be avoided if possible. As such, conservation status thresholds represent a level of population health below which the future persistence of the population segment becomes unpredictable, and will require significant management actions and time to alleviate. Biological targets identified in this Conservation Plan are based on guidelines identified through modeling exercises, found in the scientific literature, and from technical advisory committee and stakeholder team input. It is believed that the desired population status can be reached through natural processes if actions identified later in the Conservation Plan are implemented; therefore and at this time, the economic and environmental costs of directed artificial supplementation would likely outweigh the potential benefits. Unless an indicated need arises, hatchery inputs should be limited to incidental entrainment from upstream population segments.

Clear goals for the desired status of white sturgeon in the lower Columbia River and the ability to measure progress towards those goals are mandated by the NFCP. This plan will use six primary biological attributes and three secondary attributes, and their measurable criteria to describe progress towards the aforementioned goals. The primary biological attributes to be measured are:

- Abundance – the number of adult and sub-adult white sturgeon.
- Distribution – the distribution of white sturgeon within available historic habitats. These habitats include the lower Columbia River and its estuary, the Willamette River from RM 0 (Columbia River confluence) to RM 186, and Oregon coastal rivers, bays and estuaries.
- Diversity – the genetic diversity of multi-year cohorts of white sturgeon within those population segments downstream of Bonneville Dam.
- Productivity – annual age-1 recruitment, and population size structure. Recruitment, in this case, implies successfully joining a group, i.e., an age-1 recruit has survived its first year of life.
- Habitat – the amount of high quality spawning and rearing habitat across the historic freshwater and estuarine range. This range includes the lower Columbia River and its estuary, the Willamette River from RM 0 (Columbia River confluence) to RM 186, and Oregon coastal rivers, bays and estuaries.

- Persistence – the forecast likelihood that lower Columbia River white sturgeon will persist into the foreseeable future.

Secondary biological attributes considered in this Conservation Plan are:

- Growth and condition – annual growth rate of sub-adult white sturgeon and condition factor as measured by **relative weight** ( $W_r$ ).
- Natural mortality and survival – the natural (M) and total (Z) instantaneous mortality rate of lower Columbia River white sturgeon; survival is a function of total mortality.
- Fishing mortality - Fish mortality (F), as measured by sub-adult harvest of lower Columbia River white sturgeon.

As part of the ODFW process for developing the Conservation Plan for lower Columbia River white sturgeon, we constructed a **population viability analysis** (PVA) model. Our goal in creating the PVA model was to create a tool that could be used to describe the probability of lower Columbia River white sturgeon persistence, given a set of controllable input variables. Our model allows us to interpret the relative effects of various impacts, limiting factors, and threats on lower Columbia River white sturgeon, and to assess the effects of resulting management actions.

Constructing population dynamics models to reflect natural populations is complicated, even when data is plentiful and the dynamics of the population are well understood. Because of white sturgeon **longevity** and fecundity, small changes in age-specific survival rates can have large effects on populations. Given their frequency and familiarity in the literature, and their ability to provide flexibility in the face of data gaps, we used an age-based model for our population, despite acknowledged difficulties associated with aging white sturgeon (Rien and Beamesderfer 1994). What follows is a brief description of our PVA model parameters and inputs, for a full description of the PVA model and its parameterization please reference Appendix B.

Stock recruitment—Typically PVA models have a stock-recruitment function; however, for white sturgeon no such function has been developed, and may not exist (Whitlock 2007), leaving us in need of alternate methods to calculate population productivity. Given our concerns regarding white sturgeon size and age relationships, we opted to develop a rate, quantifying how many offspring survive from spawning (eggs) through their first year of life (termed egg-to-age-1 survival). Developing this rate, using techniques similar to approaches taken by other researchers when attempting to quantify egg-to-age-1 survival (Tate and Allen 2002, Jager et al 2001, Pine et al. 2001), allows a simplified model and an estimate of the number of age 1 fish produced from a given number of spawning adults.

Age 1+ survival—There are three options for survival of fish older than age-0 within the model, any of which can be used in the modeling process to compare results from various assumptions. Annual survival rates for option 1 are based on published values from Beamesderfer et al. (1995), 0.787 for juveniles and 0.95 for adults, and from DeVore et al. (1995), 0.90 for sub-adults. Option 2 is a flat annual survival rate of 95%. The third method is calculated, using a curvilinear function, and based on average weight by age (Chen and Watanabe 1989).

Predation—**Pinniped** predation on white sturgeon is extensive downstream of Bonneville Dam, though total predation related mortality is unknown. Currently U.S. Army Corps of Engineers (USACE) observation data is the only quantifiable source of predation information available.

Qualitative studies indicate that pinniped predation on white sturgeon (including reports of harbor seal predation) occurs in the river between the mouth and Bonneville Dam (ODFW, unpublished information). Although the total annual number of white sturgeon taken by pinnipeds is unknown, it is believed to pose a risk to lower Columbia River white sturgeon. Because of this potential risk, we used available information to estimate total annual predation for use in the model. A review of this estimate, projected to be 10,600 annually by 2014, and the methods used to derive it by ODFW's marine mammal biologist indicated that based on available data, this estimate was likely accurate, if a bit high (B. Wright, ODFW, personal communication).

Density dependence/carrying capacity—A density dependent mortality function was developed to offset unabated exponential increases in population growth over the course of the modeled timeframe. We created a theoretical population biomass ceiling, based on an estimated historical maximum, which could not be exceeded in the model. A curvilinear function gradually increases **natural mortality** rates as the population approaches estimated carrying capacity, and provides a reasonable limit to population size. This function was developed by running the model to equilibrium without fishery or predation removals while continually adjusting the parameters controlling the shape of the mortality function. This process was repeated until the biomass of the equilibrium population at each key life stage, i.e., age-0, juvenile, sub-adult, and adult, were as close to the estimated historical biomasses as could be achieved. While this function fits the historical estimates very well, it was not structured to mimic any specific density-dependent mechanisms.

Exploitation—Exploitation rates used in the model were derived from recent averages using tagging data. To estimate annual exploitation rates, the number of tagged fish harvested is divided by the number of tagged fish available at large over a one year period. White sturgeon may grow markedly during a one year period, and harvest fisheries are structured around specific size slots; therefore we incorporated growth into and out of legal size limits when calculating exploitation rates. A tag loss rate, based on past tag retention studies was applied when calculating exploitation.

Catch and release mortality—We applied catch and release mortality to all fisheries in the modeled population. The rate at which non-retained fish are handled is assumed to be directly proportional to the target exploitation rates specified in the model. This simplification likely does not include all catch-and-release that occurs because it only incorporates fish caught and released in pursuit of fish for harvest, not directed catch-and-release fishing, however it is the best information currently available. The model is also capable of accounting for catch-and-release angling targeted at adult fish in the area downstream of Bonneville Dam. This area remains a popular fishing destination, despite a temporal spawning sanctuary, and large numbers of oversize fish are being handled in the area annually.

Extinction thresholds—We based our criteria for extinction risks on salmon models currently in use, which largely focus on risks on a generational scale. Because female white sturgeon mature late, white sturgeon generational scales (~25 years) are decadal in length. This represents the time, on average, that a newly-hatched female white sturgeon takes to reach maturity and first spawning. We deemed a modeling time period of 500 years to be appropriate for a number of reasons: Given the longevity of white sturgeon we wanted to make sure that management actions taken today would not jeopardize persistence over a long time period, a similar approach taken for modeling Pacific salmon persistence. Many Pacific salmon models use 20 generations

for determining the effects of actions, in our case 20 generations equates to 500 years. Because of multiple spawning and year class overlap, an exact generation time is neither available nor necessary. For an extinction threshold value, we chose to use the lowest number of adult white sturgeon that have been estimated in any of the stock assessment surveys in the impounded Columbia River downstream of McNary Dam. In 2006, 250 adult fish were estimated for the population in Bonneville Reservoir (Weaver et al. 2008) – a number that has since increased (ODFW unpublished data). Thus, 250 adult fish was chosen to represent the level at which, if the population continued to decline, we would have grave uncertainty of what would occur in the future. Based on this, we set the quasi-extinction threshold (QET) at 250 adult fish for a period of 25 years or longer in a row, i.e., if the population of adult white sturgeon is < 250 per year for 25+ consecutive years, the population is assumed to be functionally extinct. This 25 year period was selected because it represents both, the length in time, as determined through sensitivity analyses, that a recruitment failure block could occur and still not crash the population as well as the approximate time it takes for a female white sturgeon to reach maturity. In the event that the modeled population size reaches 0 before the population reaches the QET definition of 250 fish or fewer for 25 sequential years, the population is also considered extinct.

**Stochasticity**—Recruitment in many fish species, including sturgeon, is correlated with environmental variables and therefore warrants incorporating a **stochastic** river flow variable that alters the baseline value for egg-to-age 1 survival based on mean river flow values. We examined 40 years of available flow data (mean daily flow from May-July) for Bonneville Dam outflow. The patterns of flow over the 40-year period were duplicated multiple times to create a long term time series from which a random starting point could be drawn. We then scaled egg-to-age 1 survival directly to the flow pattern providing a randomly selected, but co-varying range of survival rates for the model. This allows the incorporation of multiple and consecutive poor flow years as well as multiple consecutive favorable flow years in the series. The model is then run for 500 years. To repeat the process, each subsequent model run starts with the selection of a new random flow year for a starting point.

In the remainder of this section each of the chosen primary and secondary biological attributes will be accompanied by a brief description of: 1) the metrics used for assessing the attribute, 2) the evaluation thresholds for each metric for desired and conservation status, and 3) a brief description of how the metric applies to the attribute. For desired status, there are attribute targets needed to meet population performance levels for the healthy and harvestable population segment objectives. The conservation status is the attribute level that would require corrective management actions to counter declining population trends; however, it should be noted that as part of our adaptive management philosophy (as described in Section 12 of this Conservation Plan) these management actions likely would have been taken prior to reaching this level.

The population segment would be considered exceeding the desired status or falling below the conservation status, if the given metric passes a threshold. This would be true if just one measurement (e.g., a single three-year running average of sub-adult abundance) falls below the threshold. However, this should not imply that once a status threshold has been breached, the conservation trigger, or the desired goal, has been met. If, for instance, the desired abundance status is met during a single three-year running average, then the goal of the Conservation Plan for this attribute has been met; however, if during the next year it falls below that threshold, it would be considered not meeting the desired status anymore.

This section further discusses the metric measurement interval, meaning how much time passes between measurements; and lastly, the discussion and rationale for how the metric, and the desired and conservation status thresholds for each metric, were selected.

Targets for lower Columbia River white sturgeon include:

## Primary Biological Attributes

### **6.1 Adult and Sub-adult Abundance**

#### Metric

1. A three-year running average estimate of sub-adult white sturgeon abundance within the lower Columbia River population segment residing downstream of Bonneville Dam.
2. A three-year running average estimate of adult white sturgeon abundance within the lower Columbia River population segment residing downstream of Bonneville Dam.

#### Evaluation Thresholds for Abundance Metric 1

*Desired Status* – The three-year running average estimated abundance of sub-adult white sturgeon should exceed the projected amount in a given out-year (Table 7).

**Table 7.** Desired sub-adult white sturgeon abundance status levels at specified out-years.

Year	2014	2026	2036	2061	2561
Abundance	257,000	300,000	296,000	341,000	368,000

*Conservation Status* – The three-year running average estimated abundance of sub-adult white sturgeon should not fall below 31,000. At a sub-adult abundance of less than 31,000, a modeled equilibrium population size structure, and with model parameters held constant for the duration of the 500 year model run, the modeled extinction risk is  $\geq 5\%$  (See Appendix B; ODFW unpublished data).

*Metric Measurement Interval* – The abundance of sub-adult white sturgeon should be estimated annually and averaged over 3 concurrent years.

#### Evaluation Thresholds for Abundance Metric 2

*Desired Status* – The three-year running average estimated abundance of adult white sturgeon should exceed the projected amount in a given out-year (Table 8).

**Table 8.** Desired adult white sturgeon abundance status levels at specified out-years.

Year	2014	2026	2036	2061	2561
Abundance	9,250	6,250	8,650	14,250	16,250

*Conservation Status* – The three-year running average estimated abundance of adult white sturgeon is at, or below, 3,900. At an adult abundance of less than 3,900 a modeled equilibrium population size structure, and with model parameters held constant for the duration of the 500

year model run, the modeled extinction risk is  $\geq 5\%$  (See Appendix B; ODFW unpublished data).

*Metric Measurement Interval* – The abundance of adult white sturgeon should be estimated annually.

*Discussion and Rationale of Abundance Metric:*

An abundant and healthy population of white sturgeon is desired and needed. Estimating adult and sub-adult population sizes will enable us to assess the status of both, the potential spawning population and the number of fish available to seed all available habitats, including those that can only be reached by traveling through salt water, e.g., marine and estuarine, habitats. Having an estimate of the sub-adult population size should also allow us to better predict changes in the adult spawning population.

The lower Columbia River white sturgeon population segment should eventually reach a level capable of sustaining societal needs, including robust fisheries, and the long-term persistence of the population; the level should also take into account uncertainty surrounding pinniped predation and egg-to-age-1 survival. To determine this level, we estimated what the population would look like under a sustainable exploitation rate that was adjusted for current estimates of projected sea lion predation in 2014 and egg-to-age-1 survival. Because of the uncertainty surrounding these estimates, we adopted a conservative approach in our modeling by using the maximum projected pinniped predation rate and lowest observed estimated egg-to-age-1 survival and then readjusted the exploitation rate to a sustainable level that grows the population to a level that exceeds current status, even under this high predation and low productivity regime. Once this exploitation rate was determined, we reset the egg-to-age-1 survival rate to the current estimated range, left predation at the maximum projected rate, and ran the model to equilibrium, using the reduced exploitation rate. These equilibrium values were then used to define the sub-adult and adult desired status levels. This methodology, and the resulting desired status values, allows for substantial ecological and societal benefits, while maintaining a buffer against uncertainty. We have verified that this abundance level is less than our estimate of historic lower Columbia River white sturgeon carrying capacity, and will assess how this exploitation rate compares with sustainable rates determined for other long-lived highly **fecund** fish, e.g., lake sturgeon *A. fulvescens* or Pacific rockfish *Sebastes spp.*

While sustainable exploitation rates for species of sturgeon have not been widely developed and adopted, exploitation rates for Pacific rockfish and groundfish, which share similar life history traits with white sturgeon (i.e., late maturing, long-lived) have been developed (PFMC 2008) and may serve as a suitable proxy. Fishery managers have examined the Pacific groundfish fishery extensively, and have qualitatively determined exploitation rates that result in healthy populations, populations at risk of overfishing, and populations that are overfished (PFMC 2008; Punt et al. 2008). Sustainable rates for Pacific rockfish are judged to be any rate that results in 25 to 40 percent of the virgin spawning stock biomass (SSB) remaining (Brodziak 2002; PFMC 2008; Punt et al. 2008) values known as  $SB_{25}$  and  $SB_{40}$  respectively. While a similar value is not our desired status metric, we use this SSB level as a reference for our lower Columbia River white sturgeon population; therefore desired abundance status, coupled with mortality and exploitation rates identified later in this document should not result in a population dramatically less than  $SSB_{25-40}$ .

Logic dictates that desired status cannot exceed the estimated historic carrying capacity for the lower Columbia River. As part of the PVA modeling exercise we estimated the historic carrying capacity of the lower Columbia River for white sturgeon. We generated this number by assuming that prior to 1880 the lower Columbia River white sturgeon population was relatively unexploited and at theoretical carrying capacity, and then treating the biomass removed during the fishery collapse of the late 1800s as a mark-removal experiment (for a complete explanation see Appendix B). Between 1889 and 1899 a total of 18.6 million pounds of white sturgeon were landed (Craig and Hacker 1940). However, there were no reported landings in some of those years. Because fisheries were presumably ongoing for the entire period, missing landings were interpolated using a log-normal curve. We then treated the total biomass removed in the fisheries from 1889-1899, including the missing years, as an estimate of the equilibrium population biomass. The total harvest over the period was tallied and the estimated average size of white sturgeon from that window of time was used to calculate the total fishery removed biomass. We used this biomass removed as our rough estimate of Columbia River white sturgeon carrying capacity (see Appendix B). The result of this exercise indicated a carrying capacity of approximately 17 million juvenile, sub-adult, and adult white sturgeon (Appendix B) historically in the Columbia River. However, in the late 1800s the population was not fragmented by dams as it is now, and these removals occurred in areas that are currently upstream and downstream of Bonneville Dam. Therefore, we apportioned the historic carrying capacity out into current river reach, with approximately 66% of the surface area in the Columbia River downstream of McNary Dam being downstream of Bonneville Dam (Parsley and Beckman 1994). The results of this apportionment indicate an estimated lower Columbia River carrying capacity of approximately 11 million white sturgeon (Appendix B).

Taking the egg-to-age 1 survival rate, pinniped predation numbers, sustainable exploitation rates, and carrying capacity into account gives us a desired abundance status of 257,000 – 368,000 sub-adult and 6,250 – 16,250 adult white sturgeon, depending on specified out year (Tables 7 & 8). Because of their longevity, slow growth and advanced age of maturity, sturgeon populations can be vulnerable to **legacy effects** of past management actions. That is to say that past actions, e.g., overharvest in the 1980s, are still potentially influencing the white sturgeon population segment – as witnessed by the projected decline in the adult abundance over the next 5-10 years. The same life history traits that make white sturgeon vulnerable to legacy effects cause the population segment, as modeled under current conditions, (see Appendix B for model inputs) to not reach the overall desired status until late in the 500 year modeled timeframe. It was felt that some portion of this status should be reached earlier, and that progress toward that goal should be measured on a more proximate time scale. Although briefly outlined here, the adaptive management section (Section 12) of this Conservation Plan will detail timelines and checkpoints to ascertain whether the population is on track to reaching the desired status.

Conservation status levels were determined by applying the modeled equilibrium size structure (ODFW, unpublished data), to various starting population sizes in the PVA model, using the previously stated conservative estimates for egg-to-age 1 survival and predation parameters. If the starting population size, or if the modeled population size at any point during the modeled run, was less than 415,100 juvenile, 31,000 sub-adult, and 3,900 adult white sturgeon (450,000 total) and current conditions in the rest of the model inputs were held static for the duration of the 500 year model run, the population was predicted to fail in  $\geq 5\%$  of PVA model runs (see Appendix B; ODFW unpublished data). Although all parameters were held steady in the modeling effort, in reality interim status checks would indicate if the population segment were

trending toward conservation status, and our adaptive management approach would trigger management actions to stop and reverse declining trends.

## **6.2 White Sturgeon Distribution**

### Metric

The geographic distribution the lower Columbia River white sturgeon population segment throughout available habitats, including the lower Columbia River and estuary downstream of Bonneville Dam, the Willamette River to RM 186, and Oregon coastal waters, bays and estuaries.

### Evaluation Thresholds for the Distribution Metric

*Desired Status* – Lower Columbia River white sturgeon are distributed throughout and have access to all currently used habitats downstream of Bonneville Dam including the mainstem lower Columbia River and its estuary, the mainstem Willamette River including reaches both downstream and upstream of Willamette Falls, and in coastal bays, estuaries, and rivers.

*Conservation Status* – White sturgeon are determined to be locally absent from one or more of the habitats throughout its range, e.g., the Willamette River upstream of Willamette Falls, Tillamook Bay, etc. The minimum unit for a habitat is a river system or bay. For example, white sturgeon would need to be absent from the entirety of Tillamook Bay, not just the “Ghost Hole.”

*Metric Measurement Interval* – An assessment of distribution across the range of all lower Columbia River white sturgeon population segments residing downstream of Bonneville Dam should be made at least once every five years.

### *Discussion and Rationale of Distribution Metric:*

The current geographic distribution of the lower Columbia River white sturgeon population segment downstream of Bonneville Dam must be maintained. The current geographic distribution of white sturgeon within those lower Columbia River populations residing downstream of Bonneville Dam may or may not represent their historic distribution, e.g., the mainstem Willamette River upstream of Willamette Falls. However, white sturgeon currently inhabit all of the waterways described in previous sections of this conservation plan, and this distribution throughout their range represents the minimum distribution to be preserved. Preserving white sturgeon distribution throughout these areas will help buffer the population against unforeseen anthropogenic affects and environmental disturbances, and in the event of localized losses, allow for re-colonization from neighboring areas.

## **6.3 Genetic Diversity**

### Metric

The number of white sturgeon nuclear microsatellite **alleles** at 14 standardized **loci** within those lower Columbia River white sturgeon residing downstream of Bonneville Dam.

### Evaluation Thresholds for the Genetic Diversity Metric

*Desired Status* – The average number of alleles for groups of several similar aged year classes of white sturgeon (minimum number examined = 50) at 14 standardized loci is  $\geq 235$ .

*Conservation Status* – The average number of alleles for groups of several similar aged year classes of white sturgeon (minimum number examined = 50) at 14 standardized loci is < 140.

*Metric Measurement Interval* – The genetic diversity of lower Columbia River white sturgeon should be evaluated at least once per decade, a minimum of 50 individuals should be analyzed – preferably more.

#### *Discussion and Rationale of Genetic Diversity Metric:*

White sturgeon evolved over two hundred million years ago (Long 1995; Bemis et al. 1997; Bemis and Kynard 1997), and it is important to protect current lower Columbia River white sturgeon genetic diversity. Genetic diversity can provide an indicator of population health, as populations with high levels of **heterozygosity** are less likely to express deleterious alleles and genetic variability provides the raw material for adaptation and provides a buffer against **random genetic drift** (Hartl and Jones 2005; Drauch and Rhodes 2007). Those populations with a high degree of genetic diversity may have a better chance of surviving short and long-term environmental disturbances than those with a lower degree (Lande 1988; Meffe 1995; McElhany et al. 2000).

Nuclear **genetic markers** such as **microsatellites**, a type of neutral genetic marker based on a short DNA sequence that is present throughout the **genome**, can be used to detect changes in genetic diversity over time, which may be a proxy for changes in other demographic parameters (Drauch and Rhodes 2007). In addition to measuring genetic diversity, these markers may, in the future, also be used to provide an estimate of the minimum number of individuals contributing to a population, and may be more accurate than their mitochondrial counterparts (McQuown et al. 2000). An estimate of effective population size (the number of parents contributing to the population) can be used to monitor population viability in highly fecund organisms like white sturgeon (Hauser et al. 2002).

Desired and conservation status thresholds were determined in consultation with the University of California at Davis's Genomic Variation Laboratory. Microsatellite genetic diversity has not been characterized in many white sturgeon populations, though this is an area of current study (A. Drauch Schreier, UC Davis, personal communication). To establish desired and conservation status levels we looked to the Kootenai River population of white sturgeon, an endangered population. Allelic frequencies at 14 loci in the Kootenai River white sturgeon has been established at 98 (A. Drauch Schreier, UC Davis, personal communication). However, this is a population that has been isolated for ~10,000 years (Northcote 1973) without gene flow and likely originated from few founders. Therefore, we established a conservation level for lower Columbia River white sturgeon as approximately half again as high as this (140 alleles), and a desired status level of approximately 2.5 times (235 alleles) this level.

## **6.4 Productivity**

### Metric

1. The relative abundance of white sturgeon recruiting to age-1 as determined through estimating the catch per unit effort of age-0 white sturgeon sampled in fall indexing activities.
2. The estimated length frequency distribution of lower Columbia River white sturgeon.

### Evaluation Thresholds for Productivity Metric 1

*Desired Status* – Catch of age-0 white sturgeon, as determined through **age-0 indexing activities** is  $\geq 5.66$  per net.

*Conservation Status* – No age-0 white sturgeon are captured during standardized age-0 indexing activities for  $\geq 5$  consecutive years.

*Metric Measurement Interval* – Lower Columbia River white sturgeon age-0 recruitment should be indexed annually; in addition to annual reviews of recruitment, trends should be examined over longer, e.g., 3-5 years, time intervals, and a long-term trend metric such as a 10 year running geometric mean should be maintained and evaluated.

#### Evaluation Thresholds for Productivity Metric 2

*Desired Status* – The length frequency of the lower Columbia River white sturgeon population is distributed in a way that indicates a balanced, robust, productive and viable population capable of supporting societal needs with ~95% juveniles (21-38 inches FL), 4.5% being sub-adults (38-65 inches FL), and 0.5% being adults ( $\geq 66$  inches FL; see Appendix B; ODFW unpublished data).

*Conservation Status* – The length frequency distribution of lower Columbia River white sturgeon is skewed and/or distributed in such way that 60% or less of the population is composed of juvenile white sturgeon.

*Metric Measurement Interval* – The lower Columbia River white sturgeon length frequency distribution should be evaluated annually in conjunction with abundance estimation activities.

#### *Discussion and Rationale of Productivity Metrics:*

The highest periods of mortality for post larval white sturgeon are during their first year and during the time that they are within legal harvest size limits. Monitoring age-0 recruitment and population length frequency should allow the detection of any issues associated with these periods of elevated mortality forces. Productivity targets for recruitment of lower Columbia River white sturgeon were identified in NPCC 2004, through the PVA modeling exercise, and through current monitoring efforts (ODFW unpublished data).

Although some variability in recruitment over time is normal, we believe that the desired status, as determined through age-0 indexing activities, should be  $\geq 5.66$  age-0 white sturgeon per net. Although our time series does not yet exceed 10 years downstream of Bonneville Dam, this CPUE is the highest level yet encountered in ODFW monitoring activities, including both reaches downstream of Bonneville Dam (Jones 2009, ODFW unpublished data) and in the impounded reaches upstream of Bonneville Dam (Chapman and Jones 2010b, ODFW unpublished data). With the time-series caveat in place, clearly this level is attainable; however should average CPUEs in the future consistently exceed this amount by a large degree, e.g., double this rate, then this desired status metric may need to be revised. Until that time, this is our best estimate of “good” recruitment using information currently available.

The PVA model indicates that recruitment failures need to occur in consecutive long term blocks to constitute a risk to the population (see Appendix B), and although we are unsure how the levels witnessed in our age-0 indexing activities correlate to future abundances of older year classes, they are an indication of successful recruitment. Our ability to back-calculate egg-to-age-1 survival has a 5-6 year time lag, with current abundance estimates allowing us to back-

calculate up through 2004. Our age-0 indexing activities began in earnest in 2005, so within the next 5-10 years we may be able to better correlate our age-0 indexing catches with estimated egg-to-age-1 survival rates. In The Dalles Reservoir recruitment appears to have failed in two out of the last ten years, yet this reservoir continues to support a growing and productive white sturgeon population (Chapman and Weaver 2007; Chapman and Jones 2010b). The evidence from upriver reservoirs, combined with the results from the PVA modeling indicate that consecutive recruitment failures, as determined during age-0 indexing activities, exceeding 5 consecutive years may constitute issues indicating potential problems with the long term health and productivity of the population.

The lower Columbia River white sturgeon population will not have truly met desired status goals if the sub-adult and adult abundance thresholds are met by one or two year classes. To be fully considered healthy, the lower Columbia River population of white sturgeon must meet abundance targets *and* be structured across life history stages. A juvenile-dominated stock structure indicates successful recruitment is occurring regularly, and supplies replacements for sub-adult and adult mortality (Hanson et al. 1992; IPC 2005; Jager et al. 2010). Using our recently developed PVA model, we modeled the population structure after 500 years assuming current conditions. Based on this modeling effort (ODFW unpublished data), we determined that in a healthy, and therefore harvestable, population the majority (~95%) of fish  $\geq 21$  inches FL should fall in the 21 to 38 inches FL size group; a substantial number (~4.5%) in the 38 to 65 inches FL size group; and that only a small portion ( $< 0.5\%$ ) should be greater than 65 inches FL. While it is implied that fish are distributed throughout each of these size groups, it should be recognized that as fish size and therefore age, increases, the number of fish within size and age classes decreases, i.e., due to natural mortality there will be fewer 50 year old sturgeon than 30 year old sturgeon.

Healthy white sturgeon populations are dominated by juvenile white sturgeon (Hildebrand et al. 1999; IPC 2005). A white sturgeon population in which 60% or less of the population is composed of juveniles indicates a population with productivity issues (Jager et al. 2010). White sturgeon populations, even those not subject to fisheries, not dominated by juveniles have several year/size classes missing; indicating potential spawning, growth, and/or mortality issues (Hanson et al. 1992; Jager et al. 2010).

## **6.5 Spawning and Rearing Habitat**

### Metric

1. The amount of temperature conditioned weighted usable white sturgeon spawning habitat in the Bonneville Dam tailrace.
2. The amount of weighted useable age-0 white sturgeon rearing habitat.
3. The amount of weighted useable juvenile white sturgeon rearing habitat.

### Evaluation Thresholds for Habitat Metric 1

*Desired Status* – The average April – July temperature conditioned weighted usable area of white sturgeon spawning habitat in the Bonneville Dam tailrace is  $\geq 56.8$ .

*Conservation Status* – The average April – July temperature conditioned weighted usable area of white sturgeon spawning habitat in the Bonneville Dam tailrace is  $< 51.4$  (the 25<sup>th</sup> percentile for observed 1985 – 2006 values) for ten or more consecutive years.

*Metric Measurement Interval* – The amount of white sturgeon spawning habitat in the Bonneville Dam tailrace should be measured annually.

#### Evaluation Thresholds for Habitat Metric 2

*Desired Status* – The amount of weighted usable age-0 white sturgeon rearing habitat in the lower Columbia River, excluding saline portions of the estuary not accessible by age-0 white sturgeon, is greater than or equal to the level estimated in 1994 (22,240 acres) by Parsley and Beckman (1994).

*Conservation Status* – The amount of weighted usable age-0 white sturgeon rearing habitat in the lower Columbia River, excluding saline portions of the estuary not accessible by age-0 white sturgeon, is < 11,120 acres as determined using Parsley and Beckman’s (1994) methodology.

*Metric Measurement Interval* – The amount of age-0 white sturgeon rearing habitat should be evaluated every 5 years.

#### Evaluation Thresholds for Habitat Metric 3

*Desired Status* – The amount of weighted usable juvenile white sturgeon rearing habitat in the lower Columbia River, including saline portions of the estuary not accessible by age-0 white sturgeon, is greater than or equal to the level estimated in 1994 (30,888 acres) by Parsley and Beckman (1994).

*Conservation Status* – The amount of weighted usable juvenile white sturgeon rearing habitat in the lower Columbia River including saline portions of the estuary not accessible by age-0 white sturgeon, is < 15,444 acres as determined using Parsley and Beckman’s (1994) methodology.

*Metric Measurement Interval* – The amount of juvenile white sturgeon rearing habitat should be evaluated every 5 years.

#### *Discussion and Rationale of Habitat Metrics:*

Spawning habitat for lower Columbia River white sturgeon has been constrained by the construction of Bonneville Dam to the area immediately downstream of the project (Parsley et al. 1993; McCabe and Tracy 1994). This area currently provides consistent annual recruitment, and meeting productivity goals and promoting the long term health of the lower Columbia River white sturgeon population is contingent upon its protection (NPCC 2004). However, successful white sturgeon recruitment is influenced by available spawning habitat which in turn is influenced by water velocity and water temperatures. White sturgeon spawning habitat in the lower Columbia River appears to be primarily in the 7 miles of river directly downstream of Bonneville Dam (McCabe and Tracy 1994). Parsley and Beckman (1994) developed a temperature conditioned weighted useable area (WUA) index to monitor white sturgeon spawning habitat in the Bonneville Dam tailrace. The WUA index of habitat is calculated by applying a composite habitat suitability factor to the area of individual cells that were defined by transects across the river (Parsley and Beckman 1994). Thus, WUA is a unitless index that attempts to portray physical area in a biologically relevant way. To portray WUA in a temporal context (a time series analysis), we ran the model with average daily flows. We then applied yet another conditioning factor (temperature) to the daily WUA index to derive a daily temperature conditioned WUA. The daily WUA and temperature conditioned WUA indexes can be used in comparisons among years (M. Parsley, USGS, personal communication). The median value for this index between 1985 and 2006 is 56.4 (Parsley and Kofoot 2008). Because the spawning

area downstream of Bonneville Dam consistently provides white sturgeon age-0 recruitment (Parsley and Beckman 1994), the desired status was set to be above the long term average. The amount of spawning habitat in the Bonneville Dam tailrace is generally stable, even at low to moderate flows and less than ideal temperatures (Parsley and Beckman 1994). Despite this fact, production of age-0 white sturgeon in the lower Columbia River still appears to be variable (Jones 2009; ODFW unpublished data); therefore we set the conservation status for spawning habitat index at the conservative level of 51.4 (the 25<sup>th</sup> percentile of observed values between 1985 and 2006; Parsley and Kofoot 2008). Because our PVA model indicates that recruitment failures only constitute a risk to the population when they occur in long term consecutive blocks, we also applied the condition that 10 consecutive years below the 25<sup>th</sup> percentile must pass before the population is at conservation status level. Although conservation status is not reached until 10 consecutive years of sub-25<sup>th</sup> percentile have been reached, our adaptive management philosophy mandates that management actions would be taken before then to address potential impacts of permanent habitat losses or degradations as they occur and prior to reaching conservation status.

White sturgeon depend on a functional ecosystem that includes diverse and adequate seasonal food sources and contiguous habitats. Meeting abundance and stock structure goals requires a healthy mainstem and estuary ecosystem capable of sustaining white sturgeon recruitment, survival, growth, and maturation. This habitat needs to be protected, enhanced, and maintained (NPCC 2004). Age-0 and juvenile white sturgeon have similar habitat requirements, except that juvenile white sturgeon are able to **osmoregulate** in saline waters and therefore have access to more of the Columbia River estuary, and weighted useable areas for both were those calculated by Parsley and Beckman (1994). Weighted useable rearing habitat areas were generated by creating a composite suitability index, the geometric mean of depth, mid-column water velocity, and substrate **habitat suitability indices**, and multiplying this composite index by the surface area of a given cell or unit. The reach-wide weighted useable area was then calculated by summing all of the individual cell values. Pending further investigation we have set the desired status to be at least the 1994 level of weighted useable rearing habitat for both age-0 and juvenile white sturgeon. While no net loss of weighted useable rearing habitat, as defined by Parsley and Beckman (1994), should occur, a substantial decline in available habitat could constitute a risk to the population; therefore we determined conservation status to be 50% of that available in 1994 as calculated by the above authors.

Although more advanced habitat simulation tools exist they have not been developed and published for this area to date (M. Parsley, USGS, personal communication), should new habitat evaluation tools be developed in the future these spawning and rearing habitat metrics should be re-evaluated.

## **6.6 Persistence**

### Metric

The forecast likelihood that lower Columbia River white sturgeon will persist into the foreseeable future.

### Evaluation Thresholds for Persistence Metric

*Desired Status* – The average probability of persistence based on the ODFW Population Viability Analysis (PVA) model is  $\geq 0.99$ .

*Conservation Status* – The average probability of persistence based on the ODFW PVA model is  $\leq 0.95$ .

*Metric Measurement Interval* – The persistence of lower Columbia River white sturgeon should be evaluated every 3 years in conjunction with ratification of interstate-management agreements.

*Discussion and Rationale of Persistence Metric:*

We chose to adopt regionally accepted persistence metrics of  $\geq 0.99$  and  $\leq 0.95$  for desired and conservation status respectively (ODFW 2010). If the forecasted likelihood of lower Columbia River white sturgeon persistence is greater than or equal to 99%, there is a significantly higher chance that these populations can remain viable under unforeseen negative environmental or anthropogenic pressures, while continuing to provide broad environmental and societal benefits.

A PVA model for lower Columbia River white sturgeon has recently been developed by ODFW. The model developed is an age-based population model and was constructed to allow for interpretation of relative effects of various impacts on white sturgeon in the lower Columbia River and management actions that might be taken as a result. Once fully developed and peer reviewed this tool will enable fisheries managers to evaluate the long-term effects of various impacts on lower Columbia River white sturgeon.

The PVA model attempts to synthesize what is currently known regarding the size/age distribution, growth rates, sex ratio, and abundance of the population, and the age of maturity, spawning periodicity and fecundity of individual fish. This synthesis will then be combined with built in stochasticity in the form of environmental variability, natural and **fishing mortality** inputs, and annual survival rates to forecast white sturgeon population responses to differing scenarios over the next 500 years.

For a full justification for model selection, and a full explanation of model parameters and the process for deciding upon the values used to populate the parameters please see Appendix B. Although the ODFW lower Columbia River PVA model is based in principle on the Kootenai River white sturgeon PVA (Paragamian et al. 2005), and will be used for predicting persistence and assessing current status in relation to the desired and conservation status benchmarks, it has not undergone peer review. Until such time as the peer review process can be completed for this PVA model it may also be prudent to also qualitatively infer persistence by examining other factors such as those listed above. As long as the other five primary biological attributes are above conservation status and the forecasted persistence of the ODFW PVA model is greater than 95% the population can be inferred to be viable; however, should any of these attributes fall below the conservation status threshold, persistence may be in question.

## Secondary Biological Attributes

### **6.7 Growth and Condition**

#### Metric

1. The annual estimated average growth rate for lower Columbia River sub-adult white sturgeon.
2. The annual estimated average relative weight of lower Columbia River sub-adult white sturgeon.

#### Evaluation Thresholds for Growth and Condition Metric 1

*Desired Status* – The average annual growth rate of lower Columbia River sub-adult white sturgeon should be  $\geq 3.2$  inches per year, the median of 1982 – 2007 average growth.

*Conservation Status* – The annual growth rate of lower Columbia River sub-adult white sturgeon should not be  $< 1.6$  inches per year, the minimum growth rate observed between 1982 and 2007, for more than 3 years in a row unless there is an easily identifiable short-term **density-independent** (e.g., flood) or **density-dependent** (e.g., particularly strong year class) event.

*Metric Measurement Interval* – The growth of lower Columbia River white sturgeon should be evaluated annually.

#### Evaluation Thresholds for Growth and Condition Metric 2

*Desired Status* – The annual estimated average relative weight of lower Columbia River sub-adult white sturgeon should be  $\geq 100$ .

*Conservation Status* – The annual estimated average relative weight of lower Columbia River sub-adult white sturgeon should not be  $< 90$  for more than two years in a row unless there is an easily identifiable density-independent or density-dependent event.

*Metric Measurement Interval* – The condition of lower Columbia River white sturgeon should be assessed annually; trends should be evaluated over 2-5 year periods.

#### *Discussion and Rationale of Growth and Condition Metric:*

Growth rates of sub-adult white sturgeon are an important piece of information, potentially yielding valuable information about the duration of the white sturgeon life phase subject to fishing mortality. Average annual growth, based off of tagging data, of sub-adult white sturgeon was calculated for each year between 1982 and 2007 (ODFW and WDFW 2008). Growth information during this time was highly variable and non-normally distributed (ODFW, unpublished data); however, despite the observed variability there were no outliers in this data set. Because of these factors the desired status was set at the 75<sup>th</sup> percentile of observed annual growth, and the conservation status was set at the minimum observed growth.

Relative weights are a unit-less indicator of condition, and use a standardized formula to examine the relative health of the white sturgeon population. Relative weight is calculated by dividing an established standard weight for fish at a given length by the weight at time of capture of another fish of the same length, then multiplying the dividend by 100. For example, the standard weight for a 20 inch fish is 2.21 lbs., a fish this length is caught and weighs 2.19 lbs., its relative weight would be 99.5. An average relative weight of 100 is indicative of a population in good health (Anderson and Neumann 1996), and was therefore selected as the desired status. Some variability around 100 is normal for most fish populations; however, populations with average relative weights of less than 90 may be considered in poor conditions (Anderson and Neumann 1996). Therefore we chose 90 as the conservation status threshold.

## **6.8 Natural Mortality and Survival**

### Metric

1. The estimated natural mortality rate for lower Columbia River sub-adult white sturgeon.
2. The estimated annual survival of lower Columbia River adult white sturgeon.

### Evaluation Thresholds for Mortality and Survival Metric 1

*Desired Status* – The estimated natural mortality rate of lower Columbia River sub-adult white sturgeon should be  $\leq 0.09$  each year (see Appendix B; Beamesderfer et al. 1995).

*Conservation Status* – The estimated average annual natural mortality rate of lower Columbia River sub-adult white sturgeon is  $\geq 0.213$  (see Appendix B).

*Metric Measurement Interval* – The natural mortality rate of lower Columbia River sub-adult white sturgeon should be evaluated in five year averages.

#### Evaluation Thresholds for Mortality and Survival Metric 2

*Desired Status* – The estimated annual survival rate of lower Columbia River adult white sturgeon should be  $\geq 0.94$  (see Appendix B; ODFW unpublished data).

*Conservation Status* – The estimated average annual survival rate of lower Columbia River adult white sturgeon is  $\leq 0.74$  (see Appendix B).

*Metric Measurement Interval* – The annual survival rate of lower Columbia River adult white sturgeon should be evaluated in five year averages.

#### *Discussion and Rationale of Natural Mortality and Survival Metrics:*

Total mortality of sub-adult and adult life-stages of white sturgeon is composed of fishing mortality, other human influenced sources of mortality and natural sources of mortality. At this point total mortality is unknown and some of its components are poorly understood. Fishing mortality includes actual exploitation rate of retention fisheries, incidental and delayed recreational and commercial fishing mortality and illegal harvest. Other human influenced sources of mortality may include: incidental hydro-system mortality and mortality associated with commercial river navigation and recreational boating. Natural sources of mortality, excluding pinniped predation which we incorporate in our PVA separately, may include disease, **piscine** predation, and aging processes. Some potential sources of mortality, such as pollutants, contaminants, and altered predation levels may fall into both human influenced and natural sources of mortality. For the purposes of this biological attribute, all non-fishing related mortality, human related or not, is considered a part of the natural mortality component of total mortality

To ensure that white sturgeon abundance, productivity, persistence objectives are met, enough juvenile and sub-adult white sturgeon need to survive fishing and non-fishing mortality to recruit to spawning size and successfully reproduce. Current modeling indicates that population growth to the desired status abundance targets can be achieved if average annual natural (non-harvest) mortality does not exceed 10% for sub-adult white sturgeon (Beamesderfer et al 1995), and adult white sturgeon survival exceeds 95% (DeVore et al. 1995); thus we have set desired status for these metrics at these levels. Based on our modeling efforts, we have determined that long-term average sub-adult natural mortality rates in excess of 21.3% constitute a  $\geq 5\%$  persistence risk under estimates of predation and fishing rates incorporated in the model (16% annual harvest rate and 10,600 predation). Adult survival rates of  $\leq 74\%$  constitute persistence risks greater than 5% under the same assumptions.

If mortality rates exceed the levels mentioned above then additional sources of mortality may be in play, and would need to be identified, assessed, and addressed.

## **6.9 Fishing Mortality and Harvest**

### Metric

1. The three year running average of the estimated annual exploitation rate for lower Columbia River sub-adult white sturgeon.

Evaluation Thresholds for Fishing Mortality and Harvest Metric 1

*Desired Status* – The lower Columbia River white sturgeon population segment is managed to an estimated annual exploitation rate of 16% on sub-adult white sturgeon in the 38 – 54 inch FL.

*Conservation Status* – The estimated fishing exploitation rate of lower Columbia River sub-adult white sturgeon is  $\geq 29\%$  on white sturgeon 38 – 54 inches FL for  $\geq 3$  years (see Appendix B).

*Metric Measurement Interval* – The three year running average exploitation rate of lower Columbia River white sturgeon should be evaluated annually; longer-term 10-year trends should be maintained and evaluated in conjunction with management agreements.

*Discussion and Rationale of Mortality and Survival Metrics:*

As mentioned at the beginning of Section 6, the overall goal of this Conservation Plan is building a white sturgeon population segment that is both healthy *and* capable of sustaining robust, meaningful harvest opportunities. Additionally, to ensure that white sturgeon abundance, productivity, persistence objectives are met, enough juvenile and sub-adult white sturgeon need to survive fishing and non-fishing mortality to recruit to spawning size and successfully reproduce. As briefly mentioned in Section 6.8, fishing mortality includes actual exploitation rate of retention fisheries, incidental and delayed recreational and commercial fishing mortality and illegal harvest.

Our desired exploitation rate of 16% on 38 – 54 inch FL white sturgeon is that rate that allows a healthy and harvestable population segment with our best conservative estimates of pinniped predation and egg-to-age-1 survival. It should be noted that the desired exploitation rate is that exploitation rate of sub-adult white sturgeon that makes the best societal use of the resource while preserving ecological integrity and allowing abundance targets to be met, as opposed to minimizing fishing mortality. The desired harvest is the equivalent of a 16% exploitation rate on the desired 38-54 inch FL abundance projections (Table 7) and should allow harvests in excess of 40,000 in given out-years (Table 9).

**Table 9.** Desired sub-adult white sturgeon harvest status levels at specified out-years.

Year	2014	2026	2036	2061	2561
Harvest	41,000	45,000	43,000	50,000	55,000

The desired rate is also the rate that allows the population to grow and be harvested, albeit at slower and lower rates, even if egg-to-age-1 survival gets no better than our recently observed low levels. Furthermore, as modeled exploitation rates begin to exceed 16%, the projected long-term annual harvest actually begins to decline (Table 10). If exploitation rates exceed 29% on white sturgeon 38 – 54 inches FL for the *duration* of the model runs, then modeled populations fail in 5% or more of model runs. The model carries the specified exploitation rate through for the duration of each simulation; however, it is likely that significant management actions would be taken if exploitation rates consistently exceeded sustainable levels. Although exploitation rates would need to exceed 29% for long time periods to create a risk to persistence of  $\geq 5\%$ , we have set the threshold for conservation status at  $\geq 29\%$  for 3 or more years to highlight the

importance of monitoring and maintaining this metric. Additionally, should other primary biological attributes, e.g., abundance and productivity, fall to or near conservation status levels, it is assumed that management actions pertaining to fisheries would also be taken.

**Table 10.** Projected annual harvest and associated sustained exploitation rates.

Exploitation Rate	Projected Annual Harvest
0%	-
3%	20,909
6.58%	39,009
10.50%	49,086
16.64%	59,200
20.84%	54,858
25.00%	38,602
27.00%	19,618
29%	6,867

## Section 7 Current Population Status

To measure progress toward desired status we need to fully understand the current status with regards to the aforementioned biological attributes. This section will summarize the current status of lower Columbia River white sturgeon. Desired and conservation status levels identified in the previous section were based on population guidelines identified through modeling exercises, found in the scientific literature, and from technical review team input; it is unclear how current status, and how it relates to these desired and conservation levels, compares to historic status.

In this section each primary and secondary biological attribute factor will be accompanied by a summary of the current abundance status that details the best available information in relation to each of the attribute metrics; a description of the status that discusses how information regarding each metric was gathered and applied and any associated issues with the information; and an overall status evaluation of each metric that assigns an: Exceeds, Does Not Exceed, or Unknown, rating to the desired and conservation status thresholds for each metric and an accompanying brief discussion of each assigned grade.

### Primary Biological Attributes

#### **7.1 Abundance**

##### Current Abundance Status

The 2010 estimated population size for lower Columbia white sturgeon  $\geq 32$  inches FL was  $325,000 \pm 225,000$  (estimate  $\pm 95\%$  confidence interval). We apportioned this estimate among size classes and extrapolated the abundance of smaller fish using the length frequency histogram generated through 2010 lower Columbia River set-lining activities (Jones 2010). Following

these steps, we estimate the abundance of juvenile (21 – 37-inches FL), sub-adult (38-65-inches), and adult (> 65-inches FL) white sturgeon to be about 910,000, 89,000, and 11,000 fish respectively (Jones 2010). We did not derive estimates for fish smaller than 21 inches FL because they are infrequently captured on setlines. Confidence intervals cannot be calculated for the size-increment abundance estimates at this time. These estimates do not include that portion of the population residing downstream of Bonneville Dam, yet outside the mainstem lower Columbia River, e.g., coastal estuaries and nearshore marine environments.

### Discussion of Abundance Status

White sturgeon were considered “extremely abundant” based on harvest records from the turn of the century (Craig and Hacker 1940), however, precise estimates of historic abundance in the lower Columbia River are not available. For modeling purposes we used available information to develop an estimate of carrying capacity (see Appendix B). We assumed that the estimated abundance prior to commercial fisheries was the baseline for sustained capacity in the Columbia River. Between 1880 and 1900 harvest increased dramatically, and then plummeted (Figure 4), leading to the extended closure of all white sturgeon fisheries in the lower Columbia River (Craig and Hacker 1940).

The current lower Columbia River white sturgeon population, though greatly reduced from pre-settlement levels, is the largest and healthiest in the Columbia Basin and of the west coast as a whole (Smith 1990; DeVore et al. 1995) and currently supports important recreational and commercial fisheries. In the ten years between 2000 and 2009 approximately 320,000 and 85,000 white sturgeon were harvested in recreational and commercial fisheries respectively (ODFW/WDFW 2009a). To make the most informed management decisions, abundance estimates have been generated for this population annually since 1987 (except in 1994 and 2004) using mark-recapture methods (ODFW/WDFW 2007; Table 11).

During 2010 targeted white sturgeon gillnet tagging efforts, 4,628 white sturgeon were captured and measured. Of these 3,479 were tagged (ODFW unpublished data). Of the 4,628 captured and measured white sturgeon, 1,977 (42.7%) were sub-adult, legal-size fish (38 – 54 inches FL), 61 (1.3%) were adult white sturgeon above the legal-size limit (> 54 inches FL), and 1,092 (47.2%) were juveniles below the legal-size limit (< 38 inches FL; ODFW unpublished data). Approximately 74 tagged fish were removed from the mark pool through commercial and recreational retention fisheries. Returns from this tagging effort, gathered from set-line sampling activities, yielded an estimated abundance of 89,000 38 – 65 inch FL (sub-adult) white sturgeon (Jones 2010). This estimate is the first within year mark-recapture estimate generated for lower Columbia River white sturgeon and is similar in size to the 2009 estimate made using previous non-random marking and recapture methodology.

Prior to 2010, sampling to mark and recapture fish was not conducted in a random manner. This non-random type of estimate is most useful for tracking abundance trends, but less ideal for indicating specific abundance levels. While the non-random nature of marks and recoveries decrease this method’s utility as a source for point estimates, it does provide an invaluable long-term population index that should and will compliment any planned future abundance estimates.

Abundance estimates are not available for all geographic areas discussed within this conservation plan and are limited to the Columbia River. However, harvest estimates in the other areas may serve as a population index. Recreational harvest estimates exist for the Willamette River above Willamette Falls and coastal rivers, estuaries, and bays; both recreational and commercial harvest

estimates are generated for ocean caught fish. Above the Willamette Falls, recreational anglers harvested an average of  $153 \pm 20$  (mean  $\pm$  standard error [SE]) white sturgeon annually between 2000 and 2009 (Table 5), with harvest being reported as far upstream as the Coast Fork of the Willamette River (ODFW, unpublished data).

**Table 11.** Estimated abundance of 36 – 54 inches FL of lower Columbia River white sturgeon

Year	Fork Length Interval (inches)		Total
	38-42	43-54	
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	89,000	46,300	135,300
2004	N/A	N/A	N/A
2005	106,900	30,000	136,900
2006	87,500	34,000	121,500
2007	102,800	28,900	131,400
2008	65,600	31,400	97,000
2009 <sup>1</sup>	55,300	31,700	87,000

<sup>1</sup>Estimate is preliminary

From 2000 to 2009 recreational harvest in Oregon coastal tributaries has ranged from 664 to 1,462 and averaged  $938 \pm 90$  (mean  $\pm$  SE) white sturgeon annually. Recreational landings have been reported as far south as the Chetco River. Approximately one-half of the Oregon coastal recreational harvest comes from the Tillamook River Basin (ODFW, unpublished data). Ocean landings of sport caught white sturgeon from 2000 to 2009 have averaged  $133 \pm 24$  (mean  $\pm$  SE) fish in Oregon ports from Astoria in the north to Charleston in the south (ODFW unpublished data). There are no apparent trends in harvest in the Willamette River, coastal waters, or nearshore ocean recreational fisheries (Table 5). Recreational fisheries harvest in Washington

waters as varied over time with most catch currently occurring in Puget Sound and in Willapa Bay; recreational catches appear to be declining in Grays Harbor (Table 6). Commercial ocean landings of white sturgeon between 2002 and 2005 ranged from 33 – 90 lbs. Most commercially caught white sturgeon are **bycatch** from near-shore ocean trawl fisheries. No white sturgeon were taken in Oregon ocean commercial fisheries in the last five years (2006 to 2010; ODFW 2011). The magnitude of unreported bycatch is currently unknown.

Our estimate of adult population abundance (fish > 65 inches FL) should be viewed cautiously. It is based on an expansion made from a few captures of adult white sturgeon in our set lining activities, it is not possible to generate a confidence interval around it, and sampling gear is not capable of catching the largest white sturgeon, which simply rip free of the net, during tagging activities.

#### Overall Abundance Status Evaluation

Sub-adult abundance desired status = Does Not Exceed

Sub-adult abundance conservation status = Exceeds

The current (2010) estimate of 89,000 white 38 – 65 inches FL in the lower Columbia River is not at the desired status of 257,000 sub-adult white sturgeon in 2014; however, this estimate is for the geographic sub-set of the sub-adult population within the lower Columbia River proper and does not take into account those sub-adults in coastal and estuarine waters outside the Columbia River nor those residing above Willamette Falls in the Willamette River. Even when excluding these areas the current estimate is substantially above the conservation status level of 31,000.

Adult abundance desired status = Exceeds

Adult abundance conservation status = Exceeds

We have generated an adult abundance estimate of 11,000, and although there is uncertainty surrounding this estimate and it does not exceed the eventual 500 year desired status threshold, it does currently exceed our 2014 desired status level of 9,250 which leads us to the current “Exceeds” determination with regards to the desired status. This estimate is clearly also in excess of the conservation status level. The initial results from our 2009 and 2010 set-lining activities are promising and allowed us to not only develop a preliminary length frequency distribution for the lower Columbia River, but to generate the first Petersen style mark-recapture estimate for the lower Columbia River. We are planning to continue set-lining efforts in 2011 and beyond, and it is hoped that the combined fisheries dependent and independent white sturgeon stock assessments will provide our first three year average adult abundance by 2012.

## **7.2 Distribution**

### Current Distribution Status

Based on recreational and commercial fisheries, white sturgeon are present in all lower Columbia River habitats downstream of Bonneville Dam, though densities are uncertain.

### Discussion of Distribution Status

Although fisheries independent monitoring activities do not take place throughout the entire range of lower Columbia River white sturgeon habitats downstream of Bonneville Dam, recreational and commercial harvest records can give an indication of species distribution

throughout their range. Area specific harvest numbers have been consistent over the last ten years (Table 5) and this, combined with a lack of persistent barriers to historical areas indicates that white sturgeon currently are present in all water bodies downstream of Bonneville Dam where they were historically present, including coastal bays, estuaries and nearshore marine habitats. White sturgeon are also currently present in the Willamette River above Willamette Falls, though their historical use of this area is poorly understood, and have periodic access through the navigation lock and high water events such as those witnessed in 1996.

Overall Distribution Status Evaluation

White sturgeon distribution desired status = Exceeds

White sturgeon distribution conservation status = Exceeds

White sturgeon are present in all lower Columbia River habitats downstream of Bonneville Dam based on the most recent fisheries dependent and independent data available, therefore the population exceeds both the desired and conservation status thresholds.

**7.3 Genetic Diversity**

Current Diversity Status

In a recent study, the total number of alleles observed in a multi-year cohort collected in the 2000s was 241 (Drauch et al. 2009).

Discussion of Diversity Status

The genetic diversity of groups of lower Columbia River white sturgeon from the 1940s, 1980s and 2000s were recently analyzed in a collaborative University of California at Davis and ODFW effort. As mentioned previously, microsatellite genetic diversity has not been characterized in many white sturgeon populations (A. Drauch Schreier, UC Davis, personal communication). Genetic diversity appears to be variable over the last 4 white sturgeon generations with the total number of alleles (a measure of genetic diversity) observed in samples taken from multi-year white sturgeon cohorts from the 1940s, 1980s, and 2000s being 102, 216, and 241, respectively (Drauch et al. 2009). Although degradation of the samples prevented a full evaluation of samples from the 1940s, when examining eight loci of interest, the number of alleles present were 102 in the 1940s, which were not **significantly different** than the 1980s (n=101) or the 2000s (n=114; Drauch et al. 2009; Table 12). All of these are more than twice as high as Kootenai River white sturgeon allelic frequency at the same eight loci (n=46; A. Drauch Schreier, UC Davis, personal communication).

**Table12.** Genetic Diversity and estimated number of spawners of lower Columbia River white sturgeon from the 1940s, 1980s, and the 2000s. N = number of samples; A = number of alleles at eight loci of interest; A<sub>p</sub> = number of **private alleles** at eight loci of interest; N<sub>e</sub> = estimated numbers of spawners; F = number of full sibling families.

Cohort	N	A	A <sub>p</sub>	N <sub>e</sub>	F
1940s	49	102	6	-	-
1980s	76	101	2	118	2
2000s	129	114	10	210	7

## Overall Diversity Status Evaluation

White sturgeon diversity desired status = Exceeds

White sturgeon diversity conservation status = Exceeds

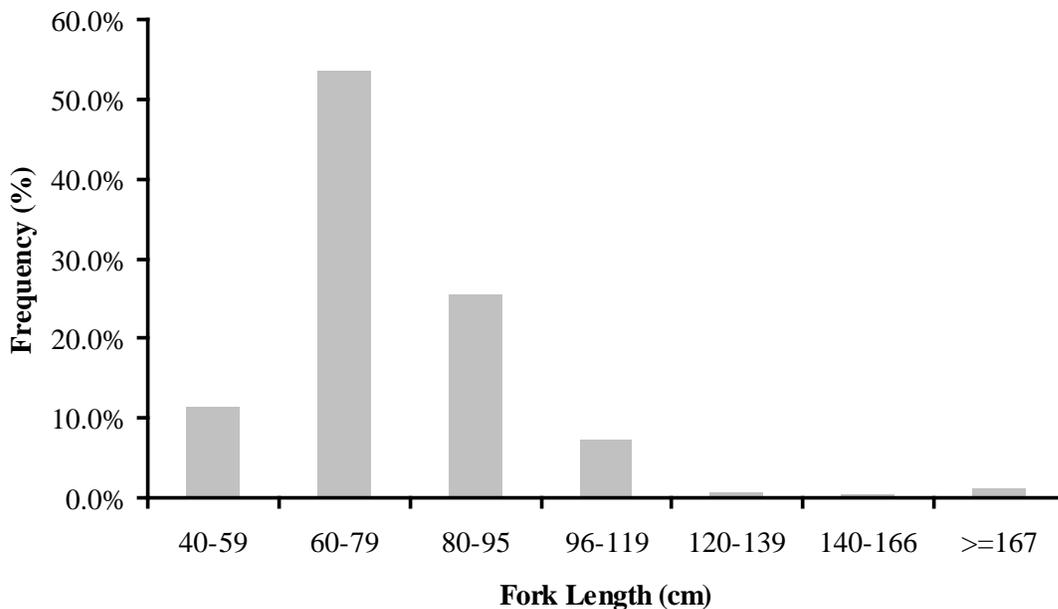
**Allelic frequencies** at 14 loci in the Kootenai River white sturgeon has been established at 98 (A. Drauch Schreier, UC Davis, personal communication). However, this is a population that has been isolated for ~10,000 years (Northcote 1973) with no gene flow followed by a severe genetic bottleneck imposed by population levels that have dropped to endangered status (USFWS 1994). Current genetic diversity in the lower Columbia River white sturgeon population is more than two and a half this level and the most recent research indicates that it might be increasing (Drauch et al. 2009). Lower Columbia River white sturgeon pass both conservation and desired status thresholds.

## **7.4 Productivity**

### Current Productivity Status

During 2009 recruitment indexing activities 5.66 age-0 white sturgeon were caught per net night (Jones 2010).

A preliminary 2010 estimate of length frequency, corrected for gear vulnerability, for lower Columbia River white sturgeon was generated through set-lining activities conducted in the summer of 2010. This indicated a population that was comprised of approximately 91% juveniles, 8% sub-adults, and 1% adults (Figure 5).



**Figure 5.** Length frequency histogram of gear vulnerability corrected of white sturgeon encountered during 2010 lower Columbia River white sturgeon set lining activities. The x-axis is fork length in centimeters and the y-axis is the percent of the total within each size class. White sturgeon less than 96-cm (38 inches) FL are juveniles, 96-166-cm (38 – 65 inches) FL are sub-adults and  $\geq 167$ -cm (66 inches) FL are adults.

### Discussion of Productivity Status

Age-0 white sturgeon recruitment observations have been reported by multiple researchers (McCabe and Tracy 1994; Chapman and Weaver 2006). McCabe and Tracy (1994) noted recruitment in the lower Columbia River while conducting white sturgeon early life history research between 1988 and 1991. In 2004, ODFW began an annual fall age-0 white sturgeon recruitment monitoring program (Chapman and Weaver 2006). This fall sampling is presumably after the period of greatest natural mortality had passed and year-class strength is established. Age-0 indexing efforts were not conducted in the lower Columbia River in 2007, but resumed in 2008. Between 2004 and 2006 and 2008-2009, indexing efforts by ODFW documented successful annual recruitment of age-0 white sturgeon (Chapman and Weaver 2006; ODFW unpublished data). Catch per net of age-0 white sturgeon increased between 2004 and 2006; a decrease was witnessed in 2008; however this was followed by a sharp increase in 2009 (Table 13; Chapman and Weaver 2006; Jones 2009, 2010).

**Table 13.** Sampling effort and catch of age-0 white sturgeon from the lower Columbia River, 2004-2006, 2008.

Parameter	Sample Year				
	2004	2005	2006	2008	2009 <sup>1</sup>
Gill net sets	78	95	96	96	96
Age-0 White sturgeon catch	101	165	180	118	543
Catch Per Net	1.29	1.74	1.88	1.23	5.66

<sup>1</sup>Preliminary data based on length frequency histograms

Nets were set in four sections of the lower Columbia River (Figure 6). Reach specific catch per net ranged from 0 in 2006 in the area closest to Bonneville Dam to nearly 14 in 2009 in the area between the Lewis and Cowlitz rivers (Figure 7).

In 2010, ODFW researchers conducted targeted white sturgeon set lining activities in the lower Columbia River. During our set lining activities we encountered and measured 1,929 white sturgeon and had a catch per line of 7.8 fish per line. During our sampling season (12 July – 16 September) we determined that average length of fish encountered in 2010 changed depending on our location. The median size of fish was negatively correlated with Columbia River mile (CRM;  $r^2 = 0.87$ ) and decreased from 39 inches FL in the lower most zone (CRM 15 – 20) to 28 inches fork length in the upper most zone (CRM 121 - 145). Median FL of white sturgeon captured in the Willamette River was 29 inches FL. A similar decline was reported during 2009 set-lining activities (Jones 2009). We also generated a length frequency histogram for white sturgeon  $\geq 21$  inches FL from this work (Figure 5; Jones 2010).

### Overall Productivity Status Evaluation

White sturgeon age-0 productivity desired status = Does not exceed

White sturgeon age-0 productivity conservation status = Exceeds

Annual age-0 indexing activities have documented reach specific and annual recruitment levels that exceed desired and conservation status thresholds (Chapman and Kern 2005; Chapman and Weaver 2006; Jones 2010). However, the 2009 level is the first time we have witnessed the 5.66

fish/net level and these measurements have only been made over a short time interval. These trends need to be evaluated over intermediate 3-5 year, and longer 5-10 year periods. When looking at age-0 recruitment at this scale, the desired productivity metric is not surpassed. As a long term productivity data set is established, a review and evaluation of this approach and metric may be warranted.

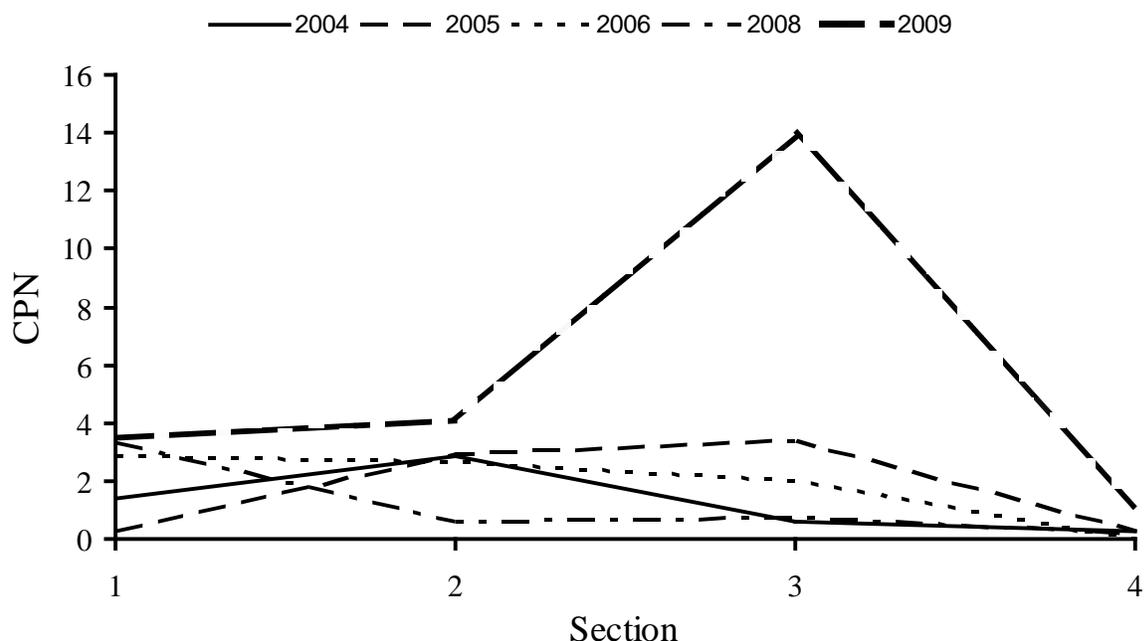
White sturgeon length frequency productivity desired status = Does Not Exceed

White sturgeon length frequency productivity conservation status = Exceeds

The current modeling effort has enabled us to define the length frequency productivity metric for our area of interest. Although the current length frequency of the population is near the desired status distribution, it is not at it. At the same time the length frequency distribution clearly indicates a population that exceeds the conservation status. Despite some caution flags being observed in recreational fisheries, i.e., recent decreases in catch per angler trip of sub-legal white sturgeon (ODFW/WDFW 2009a), the length frequency distribution is not indicating an unbalanced population. Future work will likely refine our image of the population length distribution.



**Figure 6.** Lower Columbia River ODFW age-0 sampling sections.



**Figure 7.** Catch per net of age-0 white sturgeon 2004 – 2006, 2008 – 2009 by section in the lower Columbia River. Section 1 is the most downstream section, Section 4 the most upstream.

## 7.5 Spawning and Rearing Habitat

### Current Spawning and Rearing Habitat Status

The most recent temperature conditioned WUA values are 54.8 for 2005 and 58.1 for 2006 (Parsley and Kofoot 2008); and 49.9, 70.1, and 45.4 for 2007, 2008, and 2009 respectively (ODFW unpublished data).

Rearing habitat for age-0 and juvenile white sturgeon has not been assessed since the early 1990s (Parsley and Beckman 1994).

Successful white sturgeon recruitment is influenced in part by available spawning habitat which in turn is influenced by the confluence of optimal water temperature and velocity. White sturgeon spawning habitat in the lower Columbia River appears to be limited to the 5-7 miles of river directly downstream of Bonneville Dam (Parsley et al. 1993; McCabe and Tracy 1994; Parsley and Beckman 1994). The highest quality spawning habitat, based on parameters developed by Parsley and Beckman (1994), is located approximately 2 miles downstream of Bonneville Dam, when flows are at least 74,867 cubic feet per second (cfs). Flows in this reach are generally above the 74,867 cfs threshold. Parsley and Kofoot (2008) have calculated an annual average of 56.4 of temperature conditioned WUA in the tailrace of Bonneville Dam between 1985 and 2006. In 2006, optimal flow and temperature conditions existed for approximately one week longer than in 2005 and the level of recruitment increased in 2006 (Chapman and Weaver 2006).

Rearing habitat for white sturgeon residing in habitats downstream of Bonneville Dam includes all of these waters; however, an accurate assessment of waters outside the mainstem Columbia River (i.e., the Willamette River upstream of Willamette Falls, coastal bays and estuaries, and nearshore marine habitats) does not currently exist. An assessment of these habitats should be undertaken as soon as feasible. The surface area of the Columbia River below Bonneville Dam (RM 0 to 145) is 151,475 acres, all of which is potential rearing habitat for sub-adult and adult white sturgeon (Parsley et al. 1993). Only a portion of this area is actually available to juvenile white sturgeon (Parsley and Beckman 1994) because they are still too young to leave fresh water and use brackish or saltwater portions of the estuary. Due to the size related salt tolerance factors (McEnroe and Cech 1985) associated with marine and estuarine environments, the downstream extent of usable rearing habitat is thought to be RM 28 (surface area of 63,260 acres) for age-0 white sturgeon and RM 18 (surface area of 101,800 acres) for juvenile sturgeon (Parsley and Beckman 1994). The usable portion of this area was determined by using habitat suitability indices for water depth, water column velocity, and substrate that were developed by Parsley and Beckman (1994). A habitat suitability index is a unitless value bounded by 0 and 1 and used to describe optimum habitat variables for a variety of animals, that is to say, if a fish cannot survive at a certain temperature that temperature would be rated a 0, the optimal temperature for growth and reproduction would be rated a 1. Temperatures in between are assigned intermediate values (e.g., 0.8 for good, but not optimal). Usable area is identified as having a composite suitability index score between 0.001 and 1.0 (Parsley and Beckman 1994); high quality habitat has a composite suitability index score between 0.81 and 1.0 (Parsley and Beckman 1994). Of the approximately 63,260 acres available there is 33,850 acres of usable area (16,050 acres high quality) for age-0 sturgeon. Approximately 57,100 acres of the 101,800 acres available is considered usable for juvenile white sturgeon, 19,275 acres of this is considered high quality (Parsley and Beckman 1994). Juvenile white sturgeon use a variety of rearing habitats during the course of the year (Bajkov 1951; van der Leeuw et al. 2006; Parsley et al. 2008). In the spring free swimming **embryonic** and larval stages, white sturgeon are known to use seasonally flooded riparian habitats (van der Leeuw et al. 2006). During non-winter months, age-0 and juvenile white sturgeon tend to select areas of moderate to high depth (70 ft.) with steep channel slopes and bottom roughness (Hatten and Parsley 2008, 2009). Despite salinity tolerances that would allow them access habitat as far downstream as RM 18, most juvenile white sturgeon rear upstream of RM 32 during the winter (Parsley et al. 2008). While little is known about winter habitat preferences, large congregations of juvenile, sub-adult, and adult white sturgeon near Bonneville Dam have been witnessed during winter months (U.S. Army Corps of Engineers, unpublished data). The reasons for these congregations are unknown. The exact role of coastal estuaries and marine habitats for rearing sub-adult and adult white sturgeon is currently unknown.

#### Overall Habitat Status Evaluation

White sturgeon spawning habitat desired status = Does Not Exceed

White sturgeon spawning habitat conservation status = Exceeds

The amount of temperature condition WUA has been calculated annually since 1985, and although two out of the last five years it has exceeded the desired status level it did not exceed in 2009 and the five year average (2005-2009) was less than 56.1, therefore it does not exceed desired status. However, the five year average temperature conditioned WUA does exceed the

conservation status threshold of 51.4, and only four non-consecutive years out of the last ten years have been below the conservation status threshold.

Age-0 and juvenile white sturgeon rearing habitat desired status = Unknown

Age-0 and juvenile white sturgeon rearing habitat conservation status = Exceeds

Rearing habitat for age-0 and juvenile white sturgeon has not been assessed since Parsley and Beckman's (1994) GIS exercise. How current land use practices have altered those amounts is largely unknown; however, higher quality rearing age-0 and juvenile white sturgeon habitat is typically greater than 6.5 feet in depth. This coupled with an increased regional recognition in the importance of tidal freshwater and estuarine habitats to overall ecosystem health, and recent efforts by non-governmental organizations, e.g., Lower Columbia River Estuarine Partnership, to reconnect, preserve, and protect estuarine habitats mean that the current status at a minimum likely exceeds the conservation status threshold for these metrics.

## **7.6 Persistence**

### Current Persistence Status

The results of the ODFW PVA modeling exercise, using the best assessment of current conditions forecasted persistence probability of the lower Columbia River white sturgeon population  $\geq 99\%$  (see Appendix B).

### Discussion of Persistence Status

A PVA model for lower Columbia River white sturgeon is has recently been developed ODFW biologists (ODFW, unpublished data); however is unclear whether it has realized its full analytical potential, and it has not undergone peer review. Despite these facts, we were able to forecast the likelihood of persistence at greater than 99% using a version of it populated with the best available information for current conditions. Because the PVA model has not been submitted to peer review, we felt that a qualitative review of persistence made by examining the other primary biological attributes would also be prudent. Currently, none of the other metrics for primary biological attributes fail the conservation status threshold indicating that persistence is likely; however, the status of several of them is currently unknown.

### Overall Persistence Status Evaluation

Lower Columbia River white sturgeon persistence desired status = Exceeds

Lower Columbia River white sturgeon persistence conservation status = Exceeds

As detailed above, the quantitative likelihood of persistence has been forecast at  $\geq 99\%$ , and in the review of the current status of the other five primary biological attributes above, it has been determined that none fail the conservation status threshold; therefore the desired status is preliminarily assumed to be met, pending peer review of the PVA model. Once the model has been peer reviewed these thresholds may need to be re-evaluated.

## **Secondary Biological Attributes**

### **7.7 Growth and Condition**

#### Current Growth and Condition Status

The average growth rate of sub-adult white sturgeon tagged in 2007 and at large for at least one year (365 days) is  $4.02 \pm 0.15$  inches (mean  $\pm$  SE) per year.

The median  $W_r$  for sub-adult white sturgeon collected in commercial fisheries in 2007 and 2008 is 102.

#### Discussion of Growth and Condition Status

White sturgeon growth rates in the lower Columbia River are thought to be between those of the Sacramento and Fraser river fish, with fish generally reaching 32 inches FL by age-9 (Hanson et al. 1992). Information on growth rates has been gathered from fish lengths measured during mark-recapture studies. White sturgeon between 35 and 54 inches FL in the lower Columbia River had an annual average growth rate of  $3.02 \pm 0.15$  inches (mean  $\pm$  SE) between 1982 and 2007. Annual growth rates of individuals were highly variable and no trend was apparent for the population as a whole (Figure 8). Average growth rates only fall within the 95% confidence limit of the 3.02 inches average 7 out of 26 years. Average growth of 2007 was  $4.02 \pm 0.15$  inches (mean  $\pm$  SE) per year. This represents a significant (based on 95% confidence intervals) increase of 0.66 inches from the 2006 tag group, and is the continuation of incremental increases seen since 2004. However, prior to 2005, white sturgeon annual growth in the lower Columbia River had been steadily declining (Figure 8). What variables or combination of variables influence growth rates of sub-adult white sturgeon is unclear, though they are not correlated with: discharge from Bonneville Dam ( $r^2 = 0.37$ ), smelt numbers in the lower Columbia River ( $r^2 = 0.15$ ), nor average annual Pacific Decadal Oscillation (PDO;  $r^2 = 0.14$ ; ODFW, unpublished data).

Condition, as measured by  $W_r$  of sub-adult white sturgeon in the lower Columbia River, has varied over time. Using standard weight values, adopted from Beamesderfer (1993), relative weight was calculated for over 5,000 white sturgeon collected between 1987 and 1992. Average  $W_r$  for these white sturgeon was 112 (DeVore et al. 1995). The median  $W_r$  for white sturgeon ( $n = 3,337$ ) collected in commercial fisheries in 2007 and 2008 is 102. This is an apparent decline from the value reported by DeVore et al. (1995).

#### Overall Growth and Condition Status Evaluation

Sub-adult white sturgeon annual growth and condition desired status = Exceeds

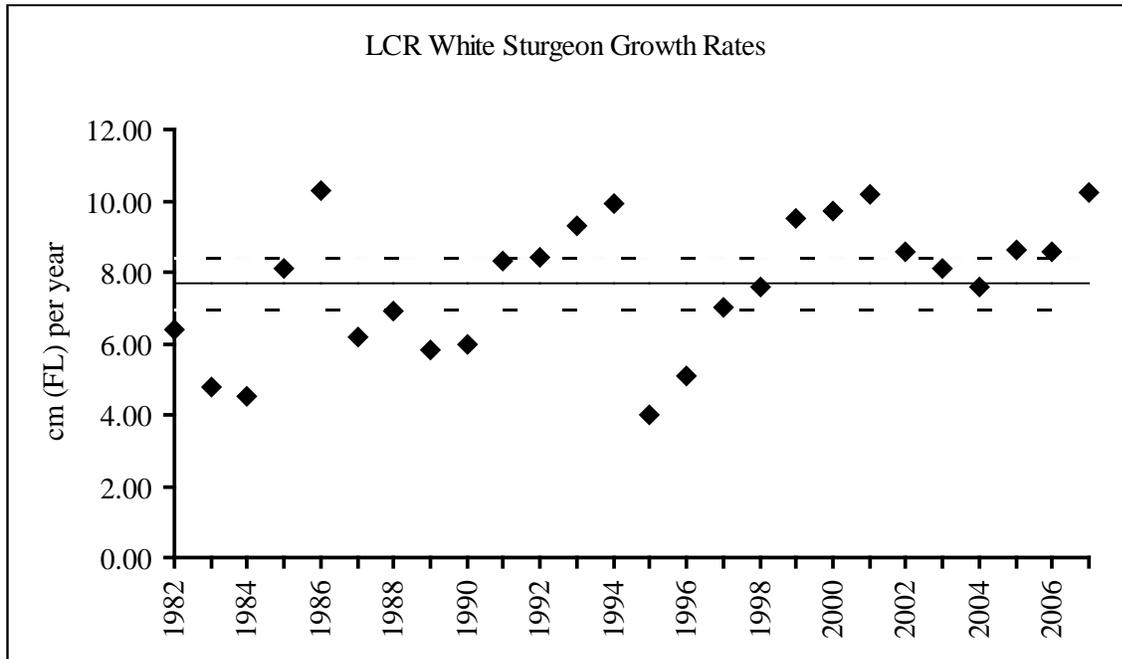
Sub-adult white sturgeon annual growth and condition conservation status = Exceeds

The current trend in annual growth of lower Columbia River sub-adult white sturgeon is up, and in 2007 surpassed both desired and conservation status thresholds. However, as mentioned above, growth is extremely variable and prior to 2007 had not exceeded the desired status threshold since 2001 (Figure 8).

Although there is an apparent decline in condition factor between 1992 and 2007-08, condition of lower Columbia River sub-adult white sturgeon still exceeds both desired and conservation status. Furthermore, the 2007-08 estimate was derived from a narrower range of sizes (38 – 59 inches FL) than the DeVore et al. (1995) estimate (21 – 104 inches FL) and any conclusions about trends in condition may be premature.

It is likely that at some abundance level growth and/or condition factor would be density dependent. However, our understanding of that level, or where we are in relation to it, is very limited. There are currently no significant relationships established between lower Columbia

River white sturgeon abundance and growth or condition. Whether this is because we are at or above the density dependent level or well below it is currently also unknown.



**Figure 8.** Annual growth rates of lower Columbia River white sturgeon tag groups at large at least one year, 1982 – 2007. Solid line is average (mean) 1982 – 2007 growth. Dashed lines are the 1982 – 2007 upper and lower 95% confidence limits.

## 7.8 Natural Mortality and Survival

### Current Natural Mortality and Survival Status

There is no current estimate of sub-adult white sturgeon natural mortality. The most recent estimate, 10%, was published by DeVore et al. (1995).

There is no current estimate of annual survival for lower Columbia River adult white sturgeon. The most recent estimates of lower Columbia River adult white sturgeon survival are 90% (DeVore et al. 1995) and 93% (Beamesderfer et al. 1995).

### Discussion of Natural Mortality and Survival Status

Mortality and survival estimates are not generated annually for lower Columbia River white sturgeon. In the past, mortality has been estimated through empirical observations and modeling efforts (Beamesderfer et al. 1995; DeVore et al. 1995). DeVore et al. (1995) derived mortality estimates from catch curves populated with an age frequency distribution of white sturgeon research catches. These estimates were generated for two groups of white sturgeon, 12 – 17-year-olds and 23 – 29-year-olds. The first group corresponded to fish in the 37 to 48 inch FL size range and represented age classes that recruited to the fishery during a time when exploitation rates were monitored (DeVore et al. 1995). The second group of white sturgeon corresponded to fish in the 60 to 69 inch FL size range and represented age classes that were no

longer subject to directed harvest (DeVore et al. 1995). **Instantaneous total mortality rate (Z)** estimates were 0.46 and 0.10 for the two groups respectively (Table 14). White sturgeon in exploitable age classes had an instantaneous fishing mortality rate (F) estimate of 0.36, and both age groups had an instantaneous natural mortality rate (M) of 0.10 (Table 14; DeVore et al. 1995). This **empirically derived estimate** of M is slightly higher than the 0.07 value predicted by Beamesderfer et al. (1995).

Neither DeVore et al. (1995), nor Beamesderfer et al. (1995) published survival estimates. However, if Z is known, annual survival (S) can be calculated using the formula  $S = e^{-Z}$  (Everhart and Youngs 1981). Using Z values published by DeVore et al. (1995), we estimated lower Columbia River white sturgeon survival in exploitable age classes at 63% annually, and those in older age classes at 90% per year (Table 14).

**Table 14.** Mortality and survival estimates for white sturgeons sampled from the Columbia River downstream from Bonneville Dam (reproduced from DeVore et al. 1995).

Parameter	Age group	
	12 - 17	23 - 29
Instantaneous total mortality (Z)	0.46	0.10
Instantaneous Fishing mortality (F)	0.36	-
Instantaneous Natural mortality (M)	0.10	0.10
Survival (S)	0.63	0.90

#### Overall Natural Mortality and Survival Status Evaluation

Sub-adult white sturgeon natural mortality desired status = Unknown

Sub-adult white sturgeon natural mortality conservation status = Exceeds (conditional)

Currently estimates of sub-adult natural mortality are unknown and unmeasured therefore its relation to desired status is unknown; however the population is well above conservation status as measured by abundance and productivity metrics so it seems likely that current natural mortality rates exceed conservation status levels. Recently implemented set-lining activities mentioned above may allow the generation of catch curves and an updated, though preliminary, estimate of sub-adult natural mortality. It is hoped that information gathered in the combined fisheries dependent and independent white sturgeon stock assessments may provide the means to generate a thoroughly updated estimate of natural mortality by 2015.

Adult survival desired status = Unknown

Adult survival conservation status = Exceeds (conditional)

Currently, annual estimates of adult survival are unknown; however the population is well above conservation status as measured by abundance and productivity metrics so it seems likely that current natural mortality rates exceed conservation status levels. It is hoped that information gathered in planned lower Columbia River white sturgeon stock assessments, coupled with ongoing modeling efforts may provide the means to generate a thoroughly updated estimate of adult survival by 2015.

## **7.9 Fishing Mortality and Harvest**

### Current Fishing Mortality and Harvest Status

The number of white sturgeon harvested in recreational and commercial fisheries in 2009 was 29,700 and 18,500 in 2010 (ODFW/WDFW 2010); the current (2011 – 2013) annual commercial and recreational combined harvest guideline is 17,000 or 22.5% of the 38-54 inch FL abundance, whichever is less.

Based on tag returns we estimate that exploitation of the lower Columbia River sub-adult white sturgeon 38 – 54 inches FL population segment averaged 24.2% between 2000 and 2008, and was 23.3% in 2008. Current preliminary estimates for 2009 and 2010 are 34.1% and 21.6% respectively, and the projected exploitation rate for 2011 is 22.5% (ODFW unpublished data) yielding a 3 year (2009-2011) running average of 26.1%. The 2011 – 2013 combined commercial and recreational annual harvest guideline is 22.5% of the 38-54 inch FL abundance or 17,000 whichever is less.

### Discussion of Fishing Mortality and Harvest Status

The harvest mandated by the current Accord for 2011 – 2013 is 17,000 or 22.5%, whichever is less. The harvest guideline is set at 17,000 and has a 2011 projected exploitation rate of 22.5%; however, because the guideline is capped at whichever is less (the number or the 22.5% exploitation rate), it is expected to drop to 16.5% in 2012 and 13.5% in 2013 due to projected population size increases.

Preliminary exploitation rates are calculated by dividing the number of fish harvested by the estimated legal size abundance. Final combined lower Columbia River exploitation rates are estimated through a marking and recapture program. For this effort, tags are released in May and June and are recovered over the course of the following year. Tag recoveries for one year following the release of annual tag groups are expanded by the fishery sampling rate of the fishery they occurred in. The number of tagged fish harvested is divided by the number of tagged fish available at large to estimate the percent exploitation rate over the one year period.

Tagged (and untagged) sturgeon may grow substantially during a one year period, and fisheries are structured around specific size limits. Therefore, incorporating some amount of growth into and out of legal size limits is necessary when calculating exploitation rates over such an extended time period. To accommodate the growth issue, we used the 10<sup>th</sup> percentile of the size at tagging for all fish recovered within 1 year to derive the lower size limit for tags from the original tag group that would comprise the at large tags available in the fisheries. We used the maximum size at tagging for all fish recovered within 1 year to define the corresponding upper bounds. Additionally, we assume a tag loss over the period of ~ 10.5%, based on past tag retention studies (DeVore et al. 1993).

### Overall Fishing Mortality and Harvest Status Evaluation

Sub-adult white sturgeon exploitation rate desired status = Does not exceed

Sub-adult white sturgeon exploitation rate conservation status = Exceeds

Recent examinations of white sturgeon mark and recapture data indicate that exploitation rates on lower Columbia River sub-adult white sturgeon is ~ 26%. While high, based on our PVA modeling exercise this is believed to be a sustainable exploitation rate; however, to optimize societal benefits while balancing ecological concerns we believe the exploitation rate should be

managed 16%, and although the our projections predict that the current harvest guideline will be less than 16% before the end of the current Accord, it is not currently so. Therefore the desired exploitation rate has not been met. However, the recent (2000-2010) exploitation rates have been for the most part, at levels below those the PVA indicated were unsustainable, and the current three year average is less than 29%; therefore the exploitation rate is not in conservation status.

### **7.10 Summary**

When looking at the current status of all primary and secondary biological attributes (Table 15), it is clear that the lower Columbia River white sturgeon population is not at its desired status. However, it seems equally clear that it is above the conservation status. No metrics measuring primary or secondary biological attributes fail to surpass the conservation status threshold (Table 15), though there are some unknowns associated with habitat and mortality metrics.

**Table 15.** Summary primary and secondary biological attributes and the metrics used to measure progress towards meeting desired and conservation status thresholds. Each metric either surpasses a threshold (Exceeds), falls below a threshold (Does Not Exceed), or its relationship to the threshold is currently unknown (Unknown). An asterisk (\*) denotes a conditional rating based on qualitative measures.

Attribute	Status	
	Desired	Conservation
Abundance		
Sub-Adult	Does Not Exceed	Exceeds
Adult	Exceeds	Exceeds
Distribution	Exceeds	Exceeds
Diversity	Exceeds	Exceeds
Productivity		
Age-0	Does Not Exceed	Exceeds
Length Frequency Distribution	Does Not Exceed	Exceeds
Habitat		
Spawning	Does Not Exceed	Exceeds*
Age-0 Rearing	Unknown	Exceeds*
Juvenile Rearing	Unknown	Exceeds*
Persistence	Exceeds	Exceeds
Growth and Condition		
Annual Growth Rate	Exceeds	Exceeds
Relative Weight	Exceeds	Exceeds
Natural Mortality and Survival		
Sub-Adult Natural Mortality	Unknown	Exceeds*
	Does Not Exceed	Exceeds*
Adult Survival	Unknown	Exceeds*
Fishing Mortality and Harvest		
Sub-Adult Exploitation	Does Not Exceed	Exceeds

# Section 8 Existing Conservation and Management Measures

## **8.1 Current White Sturgeon Population Monitoring**

White sturgeon in the lower Columbia River population segment are currently monitored through a combination of fishery independent and dependent activities done in conjunction with the Washington Department of Fish and Wildlife (WDFW) and Montana State University (MSU). 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 – 143 (B. James, WDFW, personal communication). When dead sturgeon are observed, they are counted and biological data (e.g., length, sex, maturity) are taken whenever possible. These observations are summarized and an informal report documenting sturgeon mortality is circulated to the Joint Columbia River Management Staff of ODFW and WDFW and to regional sturgeon experts and researchers.

Between May and July of each year researchers from MSU and WDFW use set-lines to capture adult white sturgeon downstream of Bonneville Dam. In addition to measuring and tagging, captured fish are examined for sex and a gonadal tissue sample is taken 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.

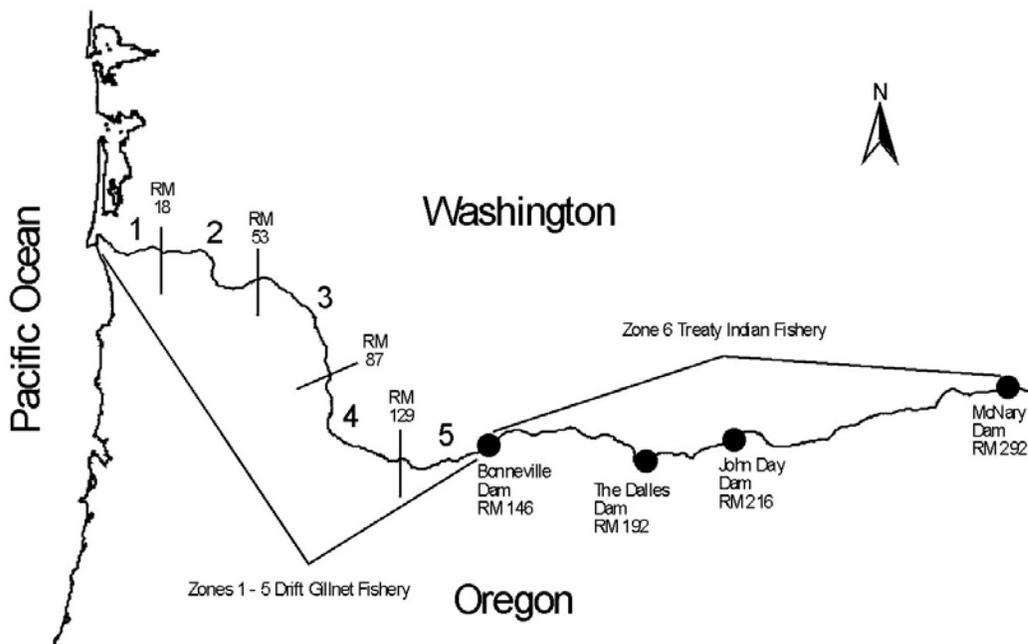
Beginning in 2004, researchers from ODFW began using small mesh gill nets to document scope and magnitude of recruitment of white sturgeon in the lower Columbia River (Chapman and Weaver 2006). Between RM 30 – 140 gill nets are set at **standardized indexing sites** to capture age-0 white sturgeon. White sturgeon captured 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  $\geq$  35 inches TL with sequentially numbered “spaghetti” tags that are inserted at the base of the dorsal fin. Recaptures of tagged fish are generally obtained from sampling the lower Columbia River recreational and commercial fisheries. Occasional recaptures and tag returns from fishing effort outside the Columbia River system have been observed. A **Petersen mark-recapture model** for closed populations is used to estimate annual abundance of harvestable, legal-size

white sturgeon each year (DeVore et al. 1999). Recruitment to harvestable size is accounted for by including recaptures of marked fish less than 42 inches TL. Marked and unmarked fish should recruit similarly and any differential survival is assumed to be negligible (DeVore et al. 1999). Although this tagging method is limited in its ability to characterize overall population status due to its non-random and size-selective nature, the long-term trend it provides is an invaluable population index.

A pilot stock assessment of lower Columbia River white sturgeon was conducted in July-August 2009 (Jones 2009). This stock assessment was repeated, with modifications to sampling design to incorporate a random selection of sites and an increase in effort, in the summer of 2010. These assessments are improving, and will continue to improve, our understanding of the size structure and condition of this white sturgeon population and 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), and is the newly adopted methodology that ODFW intends to use in out years for estimating white sturgeon abundance in the lower Columbia River. We will continue to modify and refine this sampling following the tenets of adaptive management.

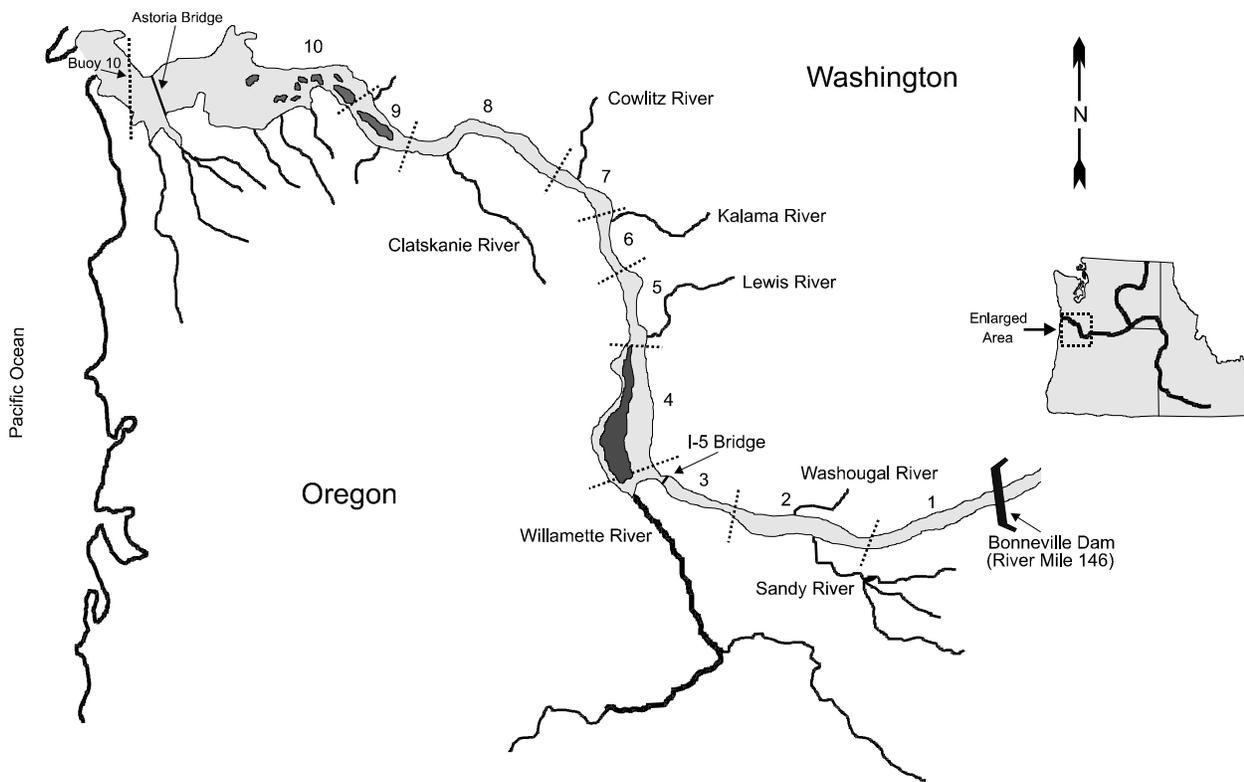
The commercial fishery in the lower Columbia River is monitored through a combination of mandatory landings reports from fish buying stations and field sampling activities to collect biological information. The goals of the monitoring activities are to determine the number and yield of the fishery by major commercial fishing zone (Figure 9).



**Figure 9.** Commercial fishing zones of the jointly managed Columbia River.

A two pronged approach is taken to accomplish these goals. Landings reports, called **fish tickets** are produced when fishers deliver fish to fish buyers, and include information on total fish weight and number of sturgeon delivered. Fish tickets must be submitted to the respective management agency within five working days. Weight information from both Washington and Oregon landings is combined to determine total yield. This method is considered more reliable than a total fish count, because of the opposing interests of sellers and buyers in determining the total fish weight associated with a sale. To determine the number and location of the fish harvested, ODFW and WDFW field crews sample a minimum of 20% 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 10). A minimum of 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, effort estimates are generated from boat and ground-based sampling activities.



**Figure 10.** Recreational sampling sections of the Columbia River below Bonneville Dam.

Personnel from ODFW and WDFW conduct random angler interviews throughout each sampling section. In addition to noting trip duration and any information on hooked fish that were not retained, they measure, weigh, and examine the catch for the presence of tags, tag scars, and missing scutes.

Catch estimates for the lower Columbia River white sturgeon recreational fishery harvest are generated by combining the total monthly effort estimates and observed catch rates in each river section and for each day type (weekday or weekend).

## **8.2 Fishery Regulation**

The lower Columbia River white sturgeon recreational and commercial fisheries 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.

Lower Columbia River white sturgeon fisheries have been managed for optimum sustained yield (OSY) since 1989. The broad definition of OSY is the allowable annual harvest that allows the maximum societal benefit from the fisheries (Roedel 1975). That is, balancing biological, ecological, economic, and sociological benefits (Nielsen 1999) from the lower Columbia River white sturgeon population. Optimum Sustainable Yield recognizes the diversity of aquatic ecosystems and the diversity of human needs in relation to them (Nielsen 1999). For lower Columbia River fisheries management purposes, OSY is defined as the harvest level that ensures sufficient numbers of juvenile white sturgeon survive fisheries so that the rate of recruitment to the broodstock population exceeds the rate of mortality for the broodstock population (DeVore et al. 1995).

Based on modeling conducted in the 1980s and 1990s, and reported in DeVore et al. 1995, the OSY annual exploitation rate was estimated to be 18% for fish 32 - 65 inches FL. Because of uncertainty in abundance and harvest estimates, fishery managers chose to implement a 3% exploitation rate **management buffer** and further reduced this exploitation rate to 15% to make certain that harvest rates would be sustainable. The 15% exploitation rate is equivalent to a 22.5% exploitation rate for fish 38 to 54 inches FL. Results from management under these exploitation rates were found to be unsatisfactory because the abundance of white sturgeon in the legal size class did not appear to be increasing, but rather declined. The decline is believed to be due to errors in the estimation of the age-growth relationship used in the original modeling. Therefore, managers opted to reduce harvest levels below those identified by the OSY exploitation rate and have set harvest levels based on population responses to management actions in recent years.

The OSY management strategy is intended to allow for the continued rebuilding of the white sturgeon population while providing harvest opportunities. As described in Section 5, the Oregon and Washington Joint State Accord depicts implementation guidelines for three-year average harvest limits that are based on the most recent abundance information. These guidelines are intended to ensure that cumulative fishery impacts do not exceed sustainable levels. Emergency actions may be taken if new information becomes available during the three

year agreement indicating significant changes in stock status. The Accord has been re-affirmed in 2000, 2003, 2006, 2010, and 2011 with adjustments made to the harvest guidelines as needed.

Using the OSY harvest and averaged 1997 to 1999 modeled population estimates of 298,700 white sturgeon 38 to 54 inches FL, a harvestable number of 67,300 white sturgeon was calculated. This was the guideline for 1997 and 1998 (ODFW/WDFW 2007). However, because the modeled population estimate was too high and modeled growth too variable, managing within the rates specified in the OSY framework yielded abundance declines of 20%. In 2000, the harvestable guideline was also dropped approximately 20% to 50,000 for the next accord. In 2002, abundances of 38 to 54 inch FL white sturgeon were still not increasing and the 2003 harvest guideline was dropped again by 20% to 40,000 to try to affect an increase in white sturgeon abundance (ODFW/WDFW 2007). In 2006, the 40,000 fish guideline was re-adopted (ODFW/WDFW 2007), and that guideline was further extended for one additional year beyond the 2006-2008 timeframe, to incorporate 2009 fishing seasons. In 2010, a one year accord was signed reaffirming many of the tenets of 2006 Accord, however the combined guideline was dropped 40% to 24,000 (J. North, ODFW personal communication). The most recent Accord was signed in 2011 for the 2011 – 2013 timeframe, again many of the objectives remain from previous Accords; however, the guideline was set annually at 17,000 or 22.5% exploitation rate, whichever is less.

Harvest goals exist for commercial and recreational fisheries. Currently, white sturgeon harvest in lower Columbia River commercial fisheries is managed to distribute landings throughout the year in order to maximize economic benefit and help distribute the catch throughout the five commercial fishing zones. Commercial fishing seasons occur during winter (January-mid March), spring (late March-mid June), summer (mid June-July), early fall (August), and late fall (late September-October) timeframes in the mainstem Columbia, and nearly year-round (February-October) in off-channel **Select Area fisheries**. In cooperation with the Commercial Advisory Group, staff from ODFW and WDFW establish season-specific harvest guidelines for each of the separate commercial fishing seasons. Harvest is then managed within those guidelines with some in-season flexibility. During the winter and late fall seasons, fishing periods designed to target white sturgeon occur. During the remainder of the year, white sturgeon harvest occurs primarily during salmon-directed fisheries. For most of the commercial seasons, weekly (per vessel) landing limits are imposed to ensure harvest remains within the season-specific guidelines, to help distribute catch throughout the fisheries, and to maintain market prices. Although individual fishers 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. Commercial fisheries, in general, have a 43 – 54 inch FL slot limit.

In 2003, the issue of allocating the recreational harvest among competing recreational interests arose. Though the goals of lower Columbia River white sturgeon recreational fisheries are to provide year-long harvest opportunities seven days per week, minimize in-season emergency action, and maintain diverse fishing opportunities, the Columbia River Recreational Fisheries Advisory Group determined that objectives differed between estuary and non-estuary white sturgeon anglers, with the Wauna power lines at RM 40 serving as a dividing line between the two areas (J. North, ODFW, personal communication).

Estuary anglers fishing downstream of the Wauna power lines were generally most interested in retention opportunities seven days per week that lasted through at least 4 July of each year.

Fishing seven days per week has been the priority in this area since 2003, even if it means concentrating fishing opportunities in a few months (Table 3). In an effort to help achieve this, the minimum size limit for this area is increased to 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.

Anglers who participated in the non-estuary fishery above the Wauna power lines were generally less concerned about fishing seven days per week and more interested in retention opportunities throughout as much of the year as possible – with a special emphasis on the spring and fall/winter (Table 3). To achieve this, a “days-per-week” approach was adopted with retention 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. Recreational fisheries upstream of the estuary are generally managed with a 38 – 54 inch FL size slot.

If these goals cannot be met, further modifications may be needed. Modifications can include reduced fishing days-per-week, season closures, reductions in individual annual bag limits, and/or other harvest regulations.

During the upcoming three year Accord (2011 – 2013), fisheries will be managed at a combined guideline of 17,000 or 22.5%, whichever is less, and the following stated commercial and recreational objectives:

- Minimize emergency in-season activities.

- Balance recreational opportunities between estuary and non-estuary anglers.

- Manage commercial fisheries to optimize economic value and to provide opportunity throughout the year.

- Maintain fishery monitoring and management capabilities.

- Reduce fishing-related handling time, stress, and mortality of spawning size white sturgeon.

### ***8.3 Water Quantity Management and Water Quality Monitoring***

The Columbia Basin Water Management Division of the USACE, Northwestern Division, is responsible for the USACE reservoir and mainstem regulation activities (primarily flood control and management of total dissolved gas) in the Columbia River Basin (USACE 2005). System-wide stream flow and hydropower project operations from head water storage projects to below Bonneville Dam are monitored in-season by the Technical Management Team (TMT), a technical group, consisting of federal, state, and tribal agencies, and chaired by a USACE representative (USACE 2008). Recommended changes to specific hydropower project operations or system flow recommendations may be made by the TMT at regularly scheduled meetings, or at other times through System Operation Requests (SORs) made by TMT members or any other interested party. The Action Agencies (USACE, Bonneville Power Administration and Bureau of Reclamation) have the final authority for implementation of any SOR. The TMT functions are intended, primarily, to oversee operations to benefit threatened or endangered

Columbia River Basin salmon, steelhead, and bull trout, as well as white sturgeon; however, the needs of other aquatic species may also be considered (USACE 2008).

Water quality monitoring in the lower Columbia River Basin is conducted primarily by the Oregon Department of Environmental Quality (ODEQ) and the Washington Department of Ecology (WDOE) (Hallock 2008, Pickett and Harding 2002) for respective state water quality regulations and the federal Clean Water Act. Other water quality monitoring efforts in the lower Columbia River are conducted by the U.S. Environmental Protection Agency (EPA 2002), the Oregon Department of Human Services (ODHS 2008), the City of Portland's Bureau of Environmental Services (Reed 2005), Columbia Riverkeepers (Columbia Riverkeepers 2008), and the U.S. Geological Survey (USGS). In 1995, the USGS National Stream Quality Accounting Network (NASQAN) Program began 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). This information can be used to determine source areas of pollutants and to assess the effects of human influences on water quality (Kelly and Hooper 1998).

Additional monitoring is conducted by other government and private entities depending on the specific programs and permits in place, and the corresponding legal responsibilities.

## Section 9. Critical Constraints, Limiting Factors and Threats

Although the lower Columbia River white sturgeon population is thought to be healthy and currently not at risk, critical constraints, limiting factors, and threats do exist that could compromise the long term health of this population. For the purpose of this document critical constraints, limiting factors and/or threats (hereafter collectively referred to as factors or impacts) are anything that negatively impacts the lower Columbia River white sturgeon population. These impacts include both biotic and abiotic factors originating within the reach and as a result of external forces. **Biotic factors**, such as marine mammal predation, can either density-dependent or independent. **Abiotic factors**, such as habitat quality and quantity, are generally density-independent physical and chemical factors in the environment. Understanding the full extent of these biotic and abiotic impacts on white sturgeon is important to the development and implementation of appropriate management actions. The following discussion of population influencing factors is intended to highlight several observed examples and potential causes, but does not provide an exhaustive list of limiting factors and constraints facing white sturgeon within this reach.

In this section each factor will be accompanied by a brief *description* of the factor detailing exactly what is meant by the factor heading; an *assessment of potential factor* describing more fully the level of influence and severity of certain impacts and the specific life stage, e.g., spawning, incubation, dispersal and rearing, that may be impacted; and the *uncertainty* detailing the level of confidence surrounding our understanding of said impact. That is to say, we may

believe that a certain factor may strongly impact certain life stages, but that we poorly understand the mechanisms or magnitude or extent of the impacts.

## **9.1 Biotic Factors**

### **9.1.1 Marine Mammal Predation**

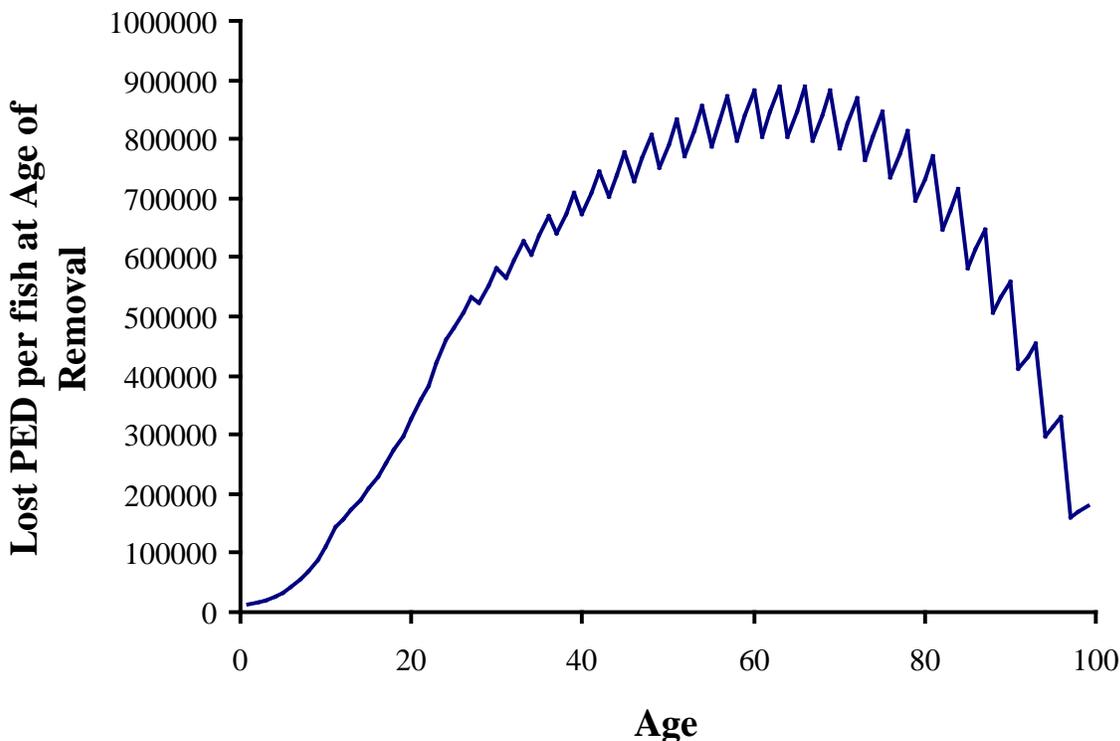
*Description* – Predation by pinnipeds, Steller sea lions (*Eumetopias jubatus*), California sea lions (*Zalophus californianus*), and harbor seals (*Phoca vitulina*), on white sturgeon in the Columbia and Willamette rivers downstream of Bonneville Dam and Willamette Falls has increased sharply in recent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

*Assessment of potential factor* – Over 20,000 hours of observations near the tailrace of Bonneville Dam between January of 2006 and May of 2010 have been recorded (Stansell et al. 2010). Predation estimates of white sturgeon generated from these observations 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. In 2006, 47% of the white sturgeon preyed upon by sea lions were greater than 48 inches TL (Stansell et al. 2009; Tackley et al. 2008a). This number decreased to 34% in 2007, and 14% in 2008 (Tackley et al. 2008a; Tackley et al. 2008b). In 2009 the percentage sturgeon that were estimated to be greater than 48 inches TL increased slightly to 20.6%, but was still below that approximately seen in the first couple of years of observations (Stansell et al. 2009; Tackley et al. 2008a). The combined increase in numbers killed and decrease in size of fish caught by sea lions is reminiscent of over-fishing witnessed in certain human fisheries (Pauly et al. 1998; Allan et al. 2005) whereby the larger individuals are removed first and subsequent fishing removes smaller-sized individuals, and may indicate a similar phenomenon. Losses of adult white sturgeon are potentially more detrimental to the population than losses of sub-adults or juvenile, even if the actual number is fewer. This can be demonstrated by looking at the potential life time egg production (Figure 11; ODFW unpublished data; Beamesderfer et al. 1995). This increase in potential egg production, to a certain age, is because adult fish have already survived natural and fishing sources mortality to make it to maturity, whereas juvenile or sub-adult are subject to these forces before they ever make it to maturity.

Marine mammal predation affects rearing and spawning life stages of lower Columbia River white sturgeon (Table 16).

*Uncertainty* – The actual magnitude of marine mammal predation related losses to lower Columbia River white sturgeon are currently unknown. The loss estimates generated by observations at Bonneville Dam are considered minimum loss estimates because: a) pinniped predation upon white sturgeon was known to occur prior to and after the sampling periods each year (Tackley et al. 2008a), and b) observations were restricted to the vicinity of Bonneville Dam, and do not take into account predation that occurs in the rest of the lower Columbia River. Staffs from WDFW and ODFW have witnessed numerous events of predation in the rest of the river, indicating that predation is occurring throughout the river. Similar reports have been provided by anglers and commercial fishers.

Although ODFW biologists have recently made an estimate of river wide pinniped predation (see Appendix B), these levels have a great deal of uncertainty, primarily regarding river wide abundance, associated with them.



**Figure 11.** Loss of potential lifetime egg deposition (PED) by age, of female white sturgeon.

### 9.1.2 Piscine Predation

*Description* – White sturgeon may be preyed upon both in freshwater and marine environments.

*Assessment of potential factor* – Predation studies have documented that white sturgeon eggs and age-0 white sturgeon are vulnerable to fish predators, including larger sturgeon (Miller and Beckman 1996; Gadomski and Parsley 2005b). In the ocean and bays, sharks may predate on sturgeons. Broadnose sevengill sharks *Notorynchus cepedianus* have been documented preying on white sturgeon in Willapa Bay, Washington (James 2008; O. Langness, WDFW, personal communication), and green sturgeon *Acipenser medirostris* have been found in the stomach contents of great white sharks *Carcharodon carcharias* (Klimley 1985). Predation experiments indicated that predation on larval white sturgeon by predator fish was negatively correlated to levels of suspended sediments, indicating that higher turbidities may make it more difficult for predators to locate and capture white sturgeon larvae (Gadomski and Parsley 2005a). The construction of the FCRPS has decreased turbidity and potentially increased predation on white sturgeon eggs, larvae, and juveniles.

Piscine predation can potentially impact all life stages of white sturgeon (Table 16).

*Uncertainty* – Although some studies have documented piscine predation on white sturgeon, the frequency and impact of this predation on white sturgeon at various life stages are poorly understood.

## **9.2 Abiotic Factors**

### **9.2.1 Habitat Quality and Quantity**

*Description* – The lower Columbia River is made up of various habitat types, such as main channel, off channel, and estuarine areas. Quantity and quality of white sturgeon habitat in the lower Columbia River has been impacted through a variety of human-caused factors.

*Assessment of potential factor* – 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. Additionally, 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). Loss or alteration of these complex spawning and rearing habitats will likely impact white sturgeon abundance in the lower Columbia River.

All life stages of lower Columbia River white sturgeon may be impacted by available habitat quality and quantity (Table 16).

*Uncertainty* – White sturgeon abundance is thought to be related to the amount of available habitat type. The magnitude of habitat alteration and/or loss in the lower Columbia River is currently poorly understood. 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.

### **9.2.2 Habitat Fragmentation**

*Description* – Construction of the FCRPS dams throughout the Columbia Basin has fragmented the once free-flowing river and altered the hydrograph in critical white sturgeon habitats (Parsley et al. 2007). River fragmentation reduces the quality and quantity of habitat, alters migration patterns, and, despite limited upstream movement at a few dams (Parsley et al. 2007), may impose unidirectional (downstream) gene flow (Jager 2006).

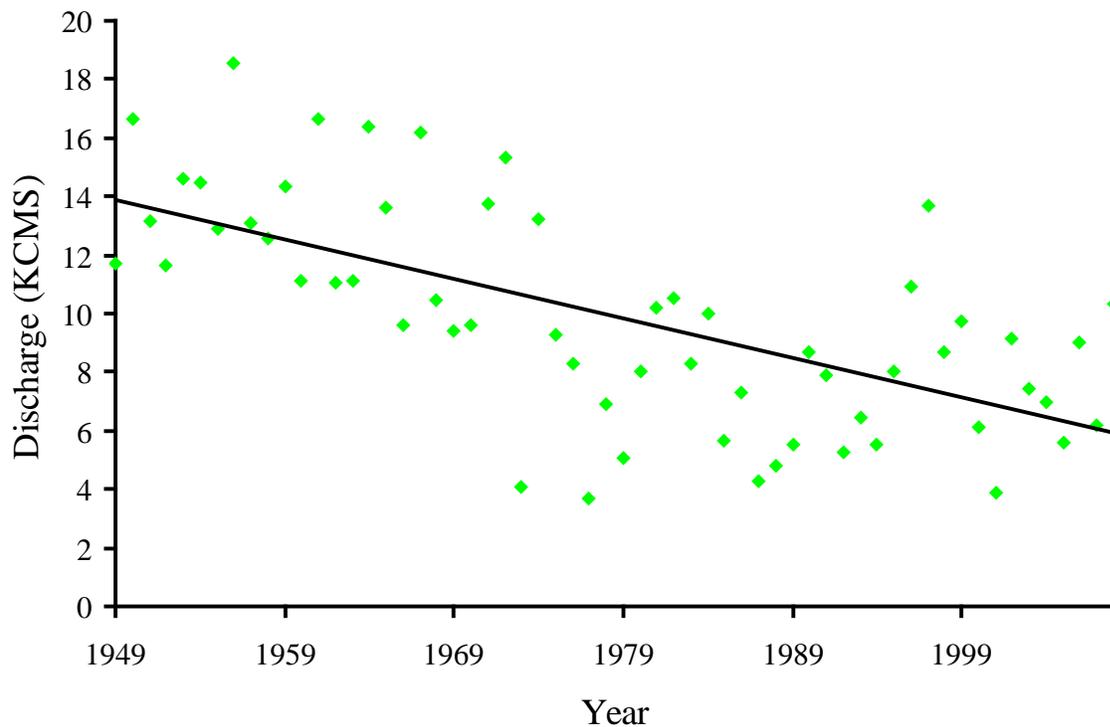
*Assessment of potential factor* – Prior to construction of the FCRPS, Columbia River white sturgeon below Bonnington Falls (Kootenay River, British Columbia, Canada) and Shoshone Falls (Snake River, Idaho, U.S.A.; Setter and Brannon 1992; IPC 2005; Paragamian et al. 2005) were one freely mixing population, able to move at will throughout the Columbia Basin. Fragmentation by hydropower development has limited this movement, because white sturgeon do not commonly use fish ladders designed primarily for Pacific salmon passage at all Columbia River dams (Warren and Beckman 1993; North et al. 1993; Parsley et al. 2007), creating connectivity and passage issues that influence nearly all life stages of Columbia River white sturgeon. White sturgeon are now less able to redistribute from areas of high densities or poor resources to seek out alternate spawning and rearing areas, and/or to access and follow seasonal food resources (NPCC 2004). This loss of connectivity has effectively created a series of isolated white sturgeon sub-populations (Jager 2006).

Habitat fragmentation affects all life stages of white sturgeon (Table 16)

*Uncertainty* – Although limited access to upstream habitats almost certainly affects lower Columbia River white sturgeon the magnitude of this affect is currently unknown.

### 9.2.3 Flow and Flow Variation

*Description* – 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% (Figure 12; Quinn and Adams 1996; Quinn et al. 1997; ODFW unpublished data), as water is stored for flood control, power generation, irrigation and recreational use. For the same time period, Columbia River winter flows have increased about 30% (Bottom et al. 2005).



**Figure 12.** Average June discharge at Bonneville Dam, 1949 through 2009.

Stream flow in the Bonneville Dam tailrace can vary hourly and daily because of electrical load-following and power peaking (Kukukla and Jay 2003). Daily and hourly oscillations between high flow levels 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.

*Assessment of potential factor* – White sturgeon spawn in high velocity habitats (Parsley et al. 1993; Perrin et al. 2003). Construction of the mainstem dams has blocked access to historic spawning habitats in the lower Columbia River. As such, the only area known to consistently provide suitable spawning habitat in the lower Columbia River exists immediately downstream

of Bonneville Dam, where dam discharge creates the high water velocities necessary for white sturgeon spawning (Parsley et al. 1993; McCabe and Tracy 1994). The area of suitable spawning habitat is known to be directly linked to the amount of spill at key times during the spawning cycle of white sturgeon (Parsley et al. 1993; Parsley and Beckman 1994).

Coutant (2004) developed a riparian habitat hypothesis for successful reproduction of white sturgeon. He suggested that eggs are either deposited in or transported to shallow seasonally-flooded riparian habitat and adhere to rocks and vegetation during incubation, and that newly-hatched yolk-sac larvae remain in shallow water habitats, seeking shelter in interstitial spaces. As water levels decline and the river returns to permanent channels, larvae metamorphose into juveniles and migrate into these channels with receding waters. Support for this hypothesis includes findings from the lower Fraser and Columbia rivers where white sturgeon eggs and larvae were found in island complexes and side channels and not in the main channel (Perrin et al. 2003; van der Leeuw et al. 2006). McCabe and Tracy (1994) showed that spawning occurs in the main channel of the Columbia River downstream from Bonneville Dam; however, the minimal sampling that has occurred for early life history stages of white sturgeon in the Ives and Pierce island complex has documented embryo's, free-swimming embryos and larvae, in side channels and riparian zones (van der Leeuw et al. 2006).

Flow and flow variation are believed to impact all life stages of white sturgeon (Table 16).

*Uncertainty* – 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).

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 may 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).

## **9.2.4 Water Quality**

### **9.2.4.1 Water Temperature**

*Description* – Water temperatures may act as a factor limiting white sturgeon spawning and recruitment. Peak spawning in the lower Columbia River occurs at 55 to 59 °F (Parsley and Beckman 1994), though some may still occur at 64 to 66 °F (McCabe and Tracy 1994).

Optimum water temperatures for the development of white sturgeon eggs and larvae are between 52 to 63 °F with negative impacts to larval development at temperatures above 63 °F (Wang et al. 1985).

*Assessment of potential factor* – **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; Table 16).

*Uncertainty* – 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 Figure 2; Figure 12), it is currently unknown what effect this may have on the white sturgeon population.

#### 9.2.4.2 Sediments

*Description* – Deposition of fine sediments in the preferred spawning habitats can result in white sturgeon egg **hypoxia**, whereby eggs die from lack of oxygen.

*Assessment of potential factor* – 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.

Sedimentation would most directly affect the incubation life stage (Table 16).

*Uncertainty* – 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 have on reproductive success is unknown. Furthermore, the bed load of suspended sediments in the Bonneville Dam tailrace tends to be low, so even if it did cause a problem for white sturgeon it would likely be a non-factor for this population.

#### 9.2.4.3 Pollutants and Contaminants

*Description* – Environmental contaminants have been detected in lower Columbia River water, sediments, and biota at concentrations above available reference levels, and 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). Numerous contaminants have been detected in research activities conducted on white sturgeon throughout the Columbia River Basin (Kruse 2000; Foster et al. 2001a and 2001b; EPA 2002). White sturgeon may uptake contaminants through direct contact or **bioaccumulation** through the food chain.

*Assessment of potential factor* – The impounding of most Columbia River reaches has resulted in increased exposure of sturgeon to contaminants trapped in sediments behind the dams. Tissue samples (liver, gonad, and cheek muscle) from immature white sturgeon in the estuary, Bonneville, The Dalles, and John Day reservoirs have been collected and analyzed for **chlorinated pesticides**, PCBs, mercury and physiological, molecular, and biochemical measures of growth and reproductive physiology. The results suggest a link between contaminants and reduced growth and reproduction (Foster et al. 2001a, 2001b; Webb et al. 2006, Feist et al. 2005), and may affect all life stages of white sturgeon to some degree (Table 16).

*Uncertainty* – Our understanding of the exact effects that pollutants and contaminants have on white sturgeon is limited. Laboratory studies have shown some pollutants to be particularly toxic to white sturgeon and correlative evidence suggests that white sturgeon may be susceptible to bioaccumulation of environmental pollutants because of their life history characteristics (long-lived, late-maturing, **benthic** association, piscivorous at larger sizes; Foster et al. 2001a; 2001b;

Feist et al. 2005; Webb et al. 2006). However, no direct link between pollutants and contaminants and abundance has been established yet.

#### **9.2.4.4 Dissolved Gases**

*Description* – 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.

*Assessment of potential factor* – 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% supersaturation and at 131% supersaturation more than 50% of larval white sturgeon died within 10 days of exposure (Counihan et al. 1998).

Dissolved gases most likely affect the dispersal life stage (Table 16).

*Uncertainty* – 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).

#### **9.2.4.5 Turbidity**

*Description* – 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).

*Assessment of potential factor* – Construction of the FCRPS dams has contributed to decreased turbidity levels potentially increasing predation on white sturgeon eggs, larvae, and juveniles. Predation experiments have indicated that predation on larval white sturgeon by sculpin, a native piscivore, is negatively correlated to levels of suspended sediments, i.e., higher turbidities make it more difficult for predators to locate and capture white sturgeon larvae (Gadomski and Parsley 2005a).

Low turbidity levels most likely affects incubation and dispersal life stages (Table 16).

*Uncertainty* – Although decreased turbidity in the Columbia River due to construction of the FCRPS undoubtedly increases predation related mortality for early life stages of white sturgeon, the actual magnitude and corresponding impact on the population is currently poorly understood.

#### **9.2.5 Fishery Effects**

*Description* – Lower Columbia River white sturgeon are subject to a variety of fisheries. Over-utilization could negatively impact lower Columbia River white sturgeon. If enough white sturgeon were removed, decreases in the numbers of white sturgeon reaching spawning sizes could reduce subsequent generations.

*Assessment of potential factor* – Because of the monetary value of white sturgeon, particularly caviar, illegal harvest is a potential threat to white sturgeon populations.

If the magnitude of established recreational and commercial fisheries were beyond sustainable levels these legal fisheries could slow the growth of or reduce the size of this population.

The handling stress associated with catch-and-release of white sturgeon  $\geq 65$  inches FL (either targeted recreational catch-and-release fishing or release of fish incidentally encountered in pursuit of legal-size fish in *both* commercial and recreational fisheries) can negatively impact reproductive adults and thus, population productivity, either through direct mortality or decreased reproductive success (Schreck 2010; Webb and Doroshov 2011). Recent research has found a strong positive correlation between “play time” and stress hormones present in the blood and that white sturgeon captured by hook and line had higher levels than those captured via set-line (Webb and Doroshov 2011). White sturgeon carcass surveys conducted by WDFW frequently find deceased white sturgeon with evidence of hooking injuries, and with fishing tackle trailing from both the mouth and the vent (WDFW, unpublished data), although the cause of mortality is often not identified and may not be associated with fishing.

Fishing effects on white sturgeon most directly impact rearing and spawning life stages (Table 16).

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

Because legal harvest is monitored and managed intensely, it is one of the few impacts that is easily quantifiable. Therefore, its impacts on the lower Columbia River white sturgeon population are better understood than many other factors.

There is no direct evidence between handling stress related to angling targeted at over-size sturgeon and reduced reproductive success in white sturgeon; though correlative evidence suggests there could be a link (Webb and Doroshov 2011), and deleterious effects associated with catch-and-release angling have been demonstrated in other fish species (Schreck et al. 2001; Beggs et al. 1980). However, a lot of variability exists surrounding these relationships in lower Columbia River white sturgeon – possibly because of multiple recaptures, i.e., even a fish that has been played for a relatively short time may have elevated stress levels at capture due to being caught several times (Webb and Doroshov 2011). The catch per trip of boat anglers in the Columbia Gorge targeting white sturgeon  $\geq 65$  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).

### 9.2.6 Incidental Hydrosystem Mortality

*Description* – 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 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).

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

Incidental hydrosystem mortality affects both spawning and rearing life stages (Table 16).

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

### 9.2.7 In-Water Work Effects

*Description* – A variety of in-water work activities, including channel maintenance, construction, and gravel extraction as well as commercial navigation occur in the lower Columbia River, and may affect white sturgeon populations within this reach. 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** *Thaleichthys pacificus*. 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. 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.

*Assessment of potential factor* – 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).

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 navigation occurring throughout the lower Columbia River 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.

All white sturgeon life stages may be impacted by in-water work in the lower Columbia River (Table 16).

*Uncertainty* – 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. Little is known about the actual magnitude or periodicity of these potential losses. Additionally, little is known about white sturgeon association with pile row habitats and what affects if any commercial navigation has on white sturgeon populations.

**Table 16.** Summary of abiotic and biotic factors and which lower Columbia River white sturgeon life stages they impact. Factors are listed by type (Abiotic or Biotic), and the certainty and impacted life stages for each factor are indicated. Each factor is given a rating of high (Hi), medium (Med), or low (Lo) detailing the severity of the impact or the level of uncertainty surrounding the factor. An uncertainty rating of “Hi” indicates that we poorly understand the effects of this factor on the life stage and population. A “Lo” uncertainty rating would imply that the potential impact is well understood.

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

## Section 10. Critical Unknowns and Data Gaps

A variety of critical unknowns and data gaps exists that could potentially impact the long-term conservation and viability of lower Columbia River white sturgeon. Identifying these unknowns and gaps is an essential step in addressing them, and moving forward with conservation efforts.

### **10.1 Uncertainty in Abundance Estimates**

A large degree of uncertainty surrounds the actual abundance of white sturgeon in the lower Columbia River. Current lower Columbia River legal-sized white sturgeon abundance estimates are generated using a Petersen mark-recapture model for closed populations. However, the marks used to generate the estimate are not applied nor recovered randomly, and the lower Columbia River is an open system. The combination of these factors violates key assumptions of

the mark-recapture model and can yield not only inaccurate estimates of abundance but they also make it difficult to know in which direction the inaccuracy lies. Furthermore, because the sampling conducted to tag and recapture fish for these estimates is focused on legal-sized fish for logistical reasons, abundance of white sturgeon outside of the legal size class is not quantifiable by this method. If an unbiased estimate of the length-frequency distribution of lower Columbia River white sturgeon were known, it could be used to expand the abundance estimate from the legal size class and thereby give an overall estimate (Weaver et al. 2008). However, the gill-nets used to capture the legal and near legal sized white sturgeon for marking are purposely size selective, as are the commercial and recreational fisheries that recover them, leaving regional scientists unable to calculate abundance of white sturgeon outside the legal size class using this method. Recent set-lining work in the summers of 2009 and 2010 in the lower Columbia River has provided some length frequency information and has allowed for an improved population estimate. This set-lining work and other possibilities should be explored and continued in order to provide the most accurate estimates possible.

The relationship between juvenile abundance and our age-0 indexing is also currently unknown, as is the relationship between egg-to-age-1 survival and our age-0 indexing. As more years of set-lining abundance estimates become available with concurrent age-0 indexing data, these relationships should become clearer and allow us to better predict future abundances from our age-0 indexing.

## **10.2 Optimal Adult Abundance Level**

The optimal abundance level for lower Columbia River adult white sturgeon is currently unknown. In other fish species, needed adult abundance levels are determined through stock-recruitment relationships and their corresponding functions. The relationship between how white sturgeon stock size and recruitment functions is not well defined. A specific stock-recruit (S-R) relationship, i.e., the number of recruits per broodstock female, is currently unknown. The development of one single relationship for white sturgeon may be difficult. It is very difficult to develop these relationships for species, such as white sturgeon, that are long lived, spawn many times over the course of their life, and are highly fecund, (Winemiller and Daily 2002). These and other factors mean that the stock-recruitment relationship likely changes as spawning stock fluctuates and spawning and rearing habitats are modified (Whitlock 2007). Additionally, the current abundance of adult female broodstock and annual recruitment to age-1 are not known and there are concerns with accurately aging older white sturgeon. An undefined stock recruitment relationship is not unique to white sturgeon, as we were unable to find published S-R relationships for any sturgeons or paddlefish. However, without a known S-R relationship it may be difficult to estimate, with traditional means, the broodstock abundance necessary, to support desired status objectives (see Section 6.1).

Further confounding the optimal adult abundance level is the lack of knowledge surrounding historic and current carrying capacity. As part of the PVA modeling exercise we did attempt to estimate historic carrying capacity (See Appendix B). Although we estimated historic carrying capacity to serve as a proxy for current carrying capacity in the PVA model, changes to the system, e.g., habitat fragmentation associated with dam construction, have likely negatively impacted river and estuary carrying capacity. This would reduce the amount of white sturgeon spawning and rearing in this habitat segment.

### **10.3 Distribution and Habitat Usage**

White sturgeon currently occupy those lower Columbia River population segment waters downstream and west of Bonneville Dam; however there are still many questions regarding the amount of white sturgeon in some of these habitats, how frequently they are used, and the rate of interchange among them.

#### **10.3.1 Actual Geographic Population Distribution**

The actual distribution, abundance, relative proportion, and interchange of white sturgeon within the study area but outside of the lower Columbia River are currently unknown. White sturgeon were previously stocked into the Willamette River above Willamette Falls (ODFW, unpublished data), and sporadic harvest records exist for the Willamette River above Willamette Falls and for the Oregon Coast (ODFW, unpublished data); however, there are no current rigorous assessments of current stock status in these areas. The origin of white sturgeon residing upstream of Willamette Falls is also uncertain. From the late 1980s to the early 2000s periodic hatchery releases of juvenile white sturgeon produced from adults collected in the Columbia River downstream of Bonneville Dam were made into this river reach, and these releases are currently believed to comprise most of the population residing there. However, there are historic reports of white sturgeon in the mainstem Willamette River as far upstream as Eugene, Oregon (Dimick and Merryfield 1945), and the entire Willamette Valley was flooded to a depth of nearly 400 feet (Allen et al. 2009) during ice age Missoula Floods. Genetic and reproductive investigations should be made of white sturgeon inhabiting this reach see if there is any genetic differentiation between areas and/or if they are naturally reproducing.

#### **10.3.2 Coastal and Marine Habitat Usage**

White sturgeon are known to move into marine environments (Bajkov 1951; Chadwick 1959; Welch et al 2006), however, the extent of their marine habitat use, the duration of marine and estuarine excursions, and the relative proportion of the population actively moving into marine environments are not known. Investigations of pectoral fin-spine micro-chemistry and acoustic telemetry studies could provide critical information for all of these issues.

### **10.4 Stock Composition of Coastal and Marine Population Components**

The origin of white sturgeon inhabiting those lower Columbia River waters west of Bonneville Dam is currently unknown. White sturgeon harvested in recreational and commercial fisheries in Oregon coastal waters, bays, estuaries, and tributaries are assumed to be of Columbia River origin. However, movement between the Sacramento, Columbia, and Fraser rivers is known to occur (Chadwick 1959; Galbreath 1985; DeVore and Grimes 1993; Watts 2006; Welch et al. 2006). It is almost certain that some mixing of white sturgeon originating in different systems occurs in Oregon coastal waters and tributaries, but the extent is unknown. Genetic analysis tools may allow the estimation of white sturgeon stock composition along the Pacific coast of North America (A. Drauch Schreier, UC Davis, personal communication).

### **10.5 Impacts of Global Climate Changes**

Global climate change is likely to have a variety of effects both physically on the lower Columbia River itself and on white sturgeon inhabiting it. Specific effects and corresponding white sturgeon responses to climate change are not well understood. While the thermal tolerance

range of adult white sturgeon may be quite broad, disease and parasites may be more prevalent in warmer waters, and several studies have documented some temperature requirements for spawning and egg incubation and survival. Spawning of the Columbia River white sturgeon typically occurs between 50 – 64° F with the peak spawning from 55 – 59° F (Parsley et al. 1993) usually in June. Egg mortality increases when incubation reaches 18° C (64° F) and total egg mortality occurs at 68° F (Wang et al. 1985). The Kootenai River white sturgeon also spawn in May or June; however, water temperatures are much cooler, about 46 - 48° F, and spawning ceases by 54° F (Paragamian et al. 2001; Paragamian and Wakkinen 2002). Eggs incubated at cooler than optimal temperatures develop normally but take longer to hatch (Wang et al. 1985). The other important factors that may be needed for successful white sturgeon recruitment are high water velocities that now occur primarily in tailrace areas below hydroelectric dams in the Columbia River Basin (Parsley et al. 2002) and submergible riparian rearing habitat (Coutant 2004). Under future scenarios of warming water temperatures and reduced summer flows there is a likely possibility that the 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, deleterious effects could be noted. Consistent annual white sturgeon reproduction in the area downstream of Bonneville dam would likely mean that the predicted lower summer flows would only decrease recruitment in this reach, on the other hand they could extinguish the already almost non-existent recruitment in much of the Columbia River Basin upstream of McNary Dam (ODFW 2005a; ISAB 2007). The effects of lost habitat quality and complexity in the estuary and tributaries could be amplified through global warming. It is unknown what affect the expected changes in hydrology and water temperatures, the loss of backwater, sloughs and other off-channel areas could have white sturgeon. Furthermore, degraded riparian habitat conditions may intensify the consequences of expected changes to flow and water temperatures by reducing stream shading, bank stabilization, food production, and nutrient and chemical mediation (Climate Impacts Group 2004; ODFW 2010).

In addition, global climate change may have impacts on the ocean environment, such as warmer temperatures and increased ocean stratification. In the past such stratification has coincided with relatively poor ocean habitat for most Pacific Northwest salmon, herring, anchovies, and smelt populations (Climate Impacts Group 2004), all potential forage for white sturgeon. How global climate change could impact other factors, such as disease or the available freshwater white sturgeon forage base is poorly understood. Without a firm understanding of these effects it is difficult to fully understand the ramifications of changing system. However, as the system changes and perhaps become more severe, the role of certain stressors as a population regulatory factor likely will become more prominent.

## **10.6 Population Viability**

Although white sturgeon in the lower Columbia River are abundant, are known to spawn regularly, and produce measurable recruitment annually, the probability that the lower Columbia River white sturgeon population will persist in perpetuity has only recently been estimated as part of our PVA modeling efforts. Although chances for long term persistence can be augmented with mitigation and management techniques, it can be difficult for resource managers and regional stakeholders to perceive the benefits of alternate approaches without a modeling tool. The age-based PVA model we developed is such a tool (see Appendix B). Using an iterative

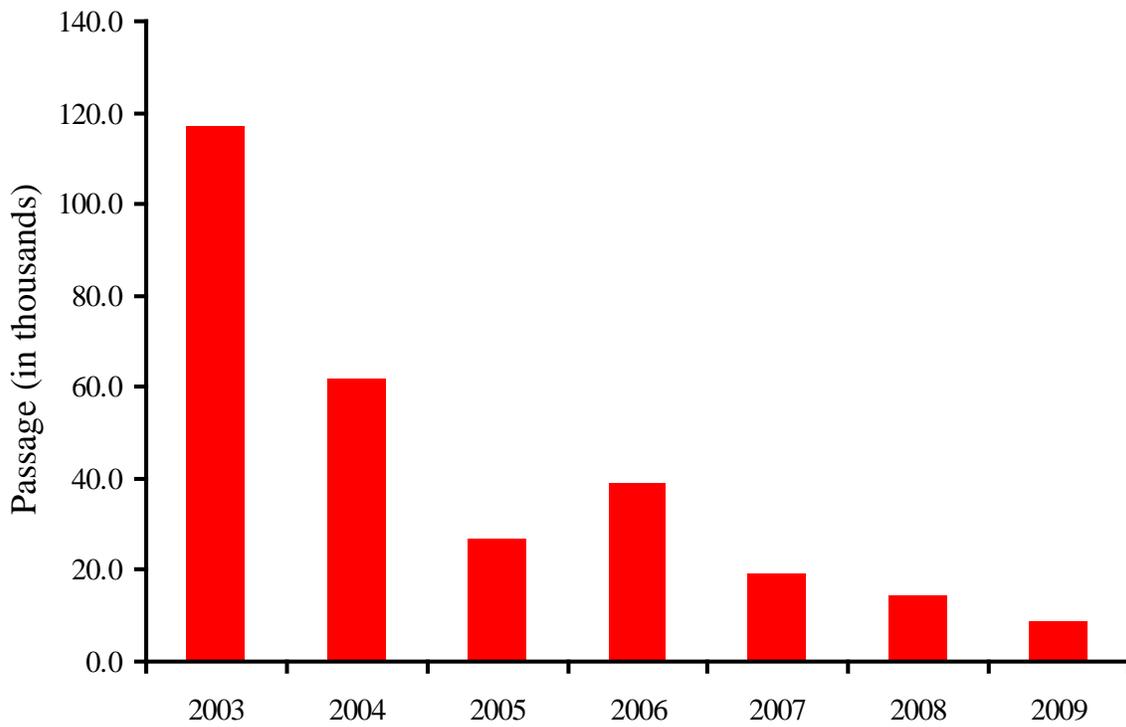
process, the PVA can evaluate various risks to long-term persistence of lower Columbia River white sturgeon (Jager et al. 2001). Although a PVA model has been developed and peer reviewed for middle Snake River white sturgeon populations (Jager et al. 2000), the current lower Columbia River PVA model has only gone through the development stages. Until this peer review process can be completed with our PVA model, uncertainty in our persistence forecasts will not dissipate. Furthermore, population viability modeling techniques other than those utilized by ODFW exist, for instance Jager et al. (2000) developed an individual based population viability model for Snake River populations of white sturgeon as opposed to the age-structured population simulation model we selected. Concerns about intensive data needs that currently outstrip available information have made using individual based-modeling impractical for our population despite its extremely flexible platform (See Appendix B); however, in the future, information availability may meet this modeling approach's needs and at that time it could be revisited.

### **10.7 Available Native Forage Species**

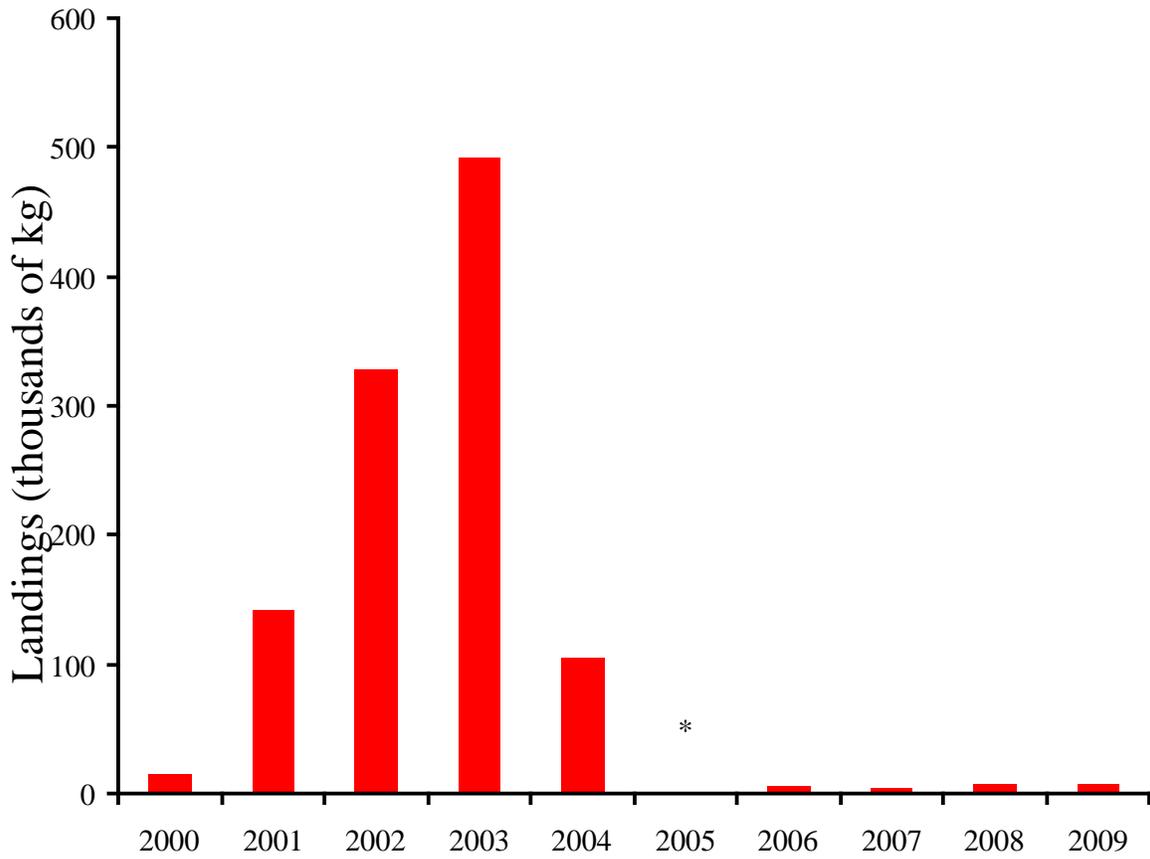
White sturgeon are food generalists, with diets that vary seasonally, with age, and by location (Hanson et al. 1992). Native forage can include invertebrates, eulachon eggs, and seasonally abundant eulachon and Pacific lampreys *Lampetra spp.* (Bajkov 1949; Muir et al. 1988; Hanson et al. 1992; McCabe et al. 1993; Romano et al. 2002). White sturgeon < 31 inches TL feed mainly on invertebrates, with **amphipods** being the most often selected prey items (McCabe et al. 1993; Romano et al. 2002). McCabe et al. (1993) also noted that a substantial portion of the diet for white sturgeon in this size class consists of eulachon eggs and Asian clams *Corbicula fluminea*. Although native invertebrates, including amphipods and mollusks, are an important component of rearing white sturgeon diets, their relative abundance is currently unknown. As white sturgeon grow, their diets become more diverse and commonly include fish (Bajkov 1949; Muir et al. 1988; Hanson et al. 1992; Romano et al. 2002) including seasonally abundant Pacific lampreys, eulachon, and American shad *Alosa sapidissima*. Returns of native white sturgeon forage fish, e.g., eulachon and Pacific lamprey, to the Columbia River are currently at low levels compared to historic levels (ODFW/WDFW 2002; ODFW/WDFW 2008; FPC 2010a; Gustafson et al. 2010), and the southern DPS of eulachon has recently been listed as threatened under the Endangered Species Act (NMFS 2010).

Pacific lampreys were an important food source for adult white sturgeon historically (Bajkov 1951; McCabe et al. 1993; NPTFRMS 2005). In the last seven years (2003 to 2009) numbers of lamprey passing Bonneville Dam have decreased dramatically, from over 115,000 individuals in 2003, to less than 9,000 in 2009 (FPC 2010a; Figure 13).

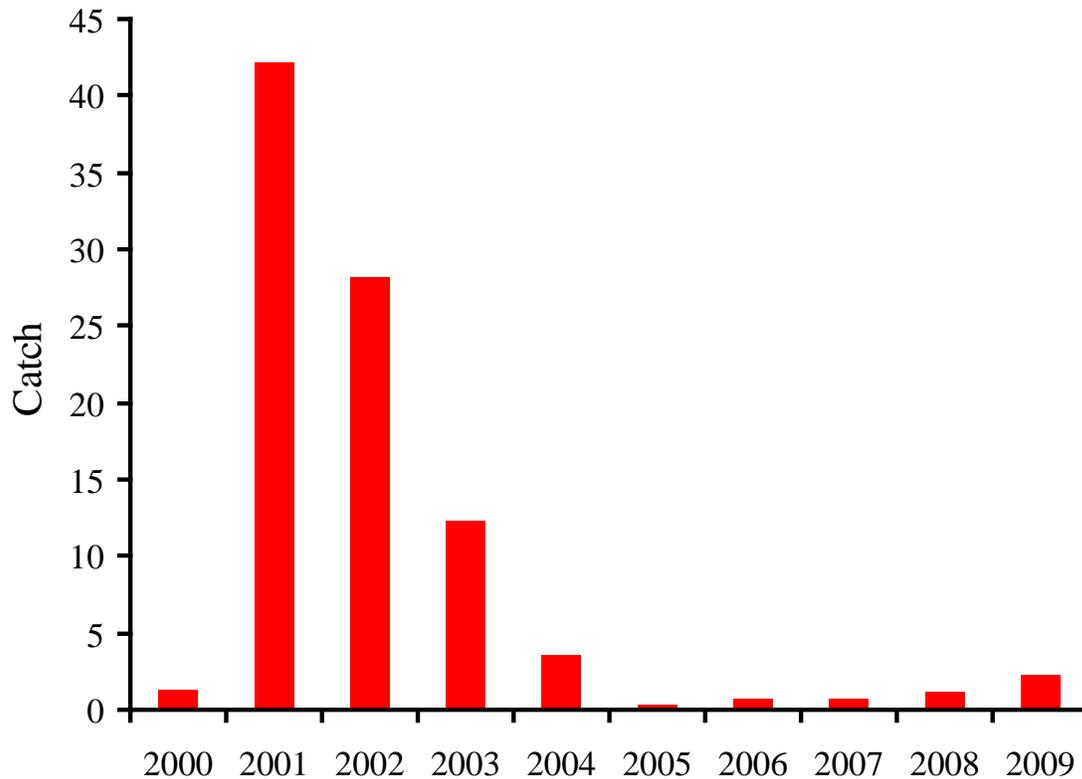
Eulachon, both eggs and fish, are an important food source for lower Columbia River white sturgeon (Bajkov 1951; Semakula and Larkin 1968; Muir et al. 1988; McCabe et al. 1993; Romano et al. 2002). However, returns of eulachon to the Columbia River are currently at very low levels. Commercial landings since 2000 have fluctuated, decreasing from a peak of 540 tons in 2003 to approximately 8.8 tons in 2008 (Figure 14; ODFW/WDFW 2009a). If the average size of these fish was similar to past levels (Gustafson et al. 2010) this would equate to approximately 193,000 adult eulachon. Fisheries independent monitoring of larval eulachon in the lower Columbia River has also revealed recent substantial declines in density (Figure 15; ODFW/WDFW 2009a). Furthermore, eulachon have been listed as threatened under the Endangered Species Act (NMFS 2010).



**Figure 13.** Upstream adult lamprey passage (in thousands) at Bonneville Dam. Lamprey passage monitoring protocols changed from 24-h monitoring to 16-h monitoring (04:00 – 20:00) in 2003.



**Figure 14.** Commercial landings, in thousands of kilograms, of eulachon from the lower Columbia River and tributaries. \* in 2005 commercial eulachon landings totaled 90.7 kg.



**Figure 15.** Number (n) per cubic meter (m<sup>3</sup>) of eulachon larvae detected in mainstem Columbia River fisheries independent sampling activities.

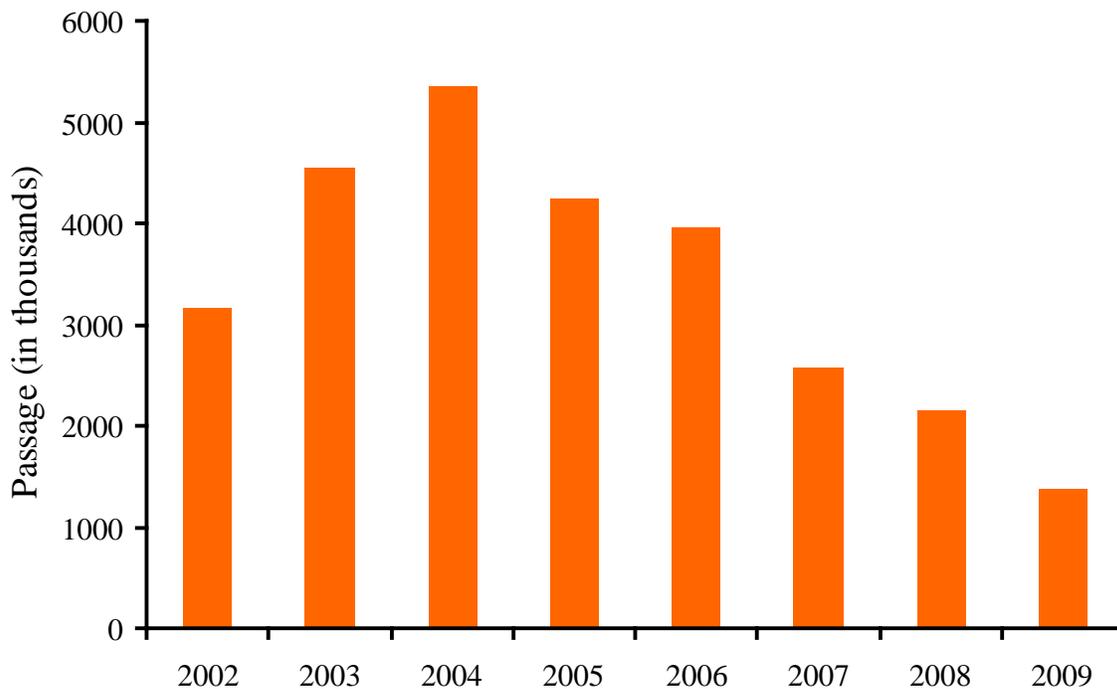
The contribution of Pacific anchovy *Engraulis mordax* to white sturgeon diets is poorly understood – though it seems likely that for estuary and ocean residing white sturgeon that they are seasonally important. Landings of anchovy in the last 10 years have ranged, without apparent trend, from a low of 0 lbs. in 2001 to 572,201 lbs. in 2008; the 2010 estimate was 304,873 lbs.

The status of these forage fish may impact white sturgeon in this river reach; however the affects and magnitude of the shifts in abundance of forage fish have on white sturgeon are not well understood. Community assemblages, abundances, densities of native invertebrate populations, such as amphipods and mollusks, which are important food resources for white sturgeon (McCabe et al. 1993; Romano et al. 2002), and how this forage base might change through time, are unknown and not currently assessed in the lower Columbia River. Although all of these native forage species are known to be important to lower Columbia River white sturgeon diets, the relative importance of each or how their abundance and density my change through time, is not well understood.

### **10.8 Introductions of Non-Native Species**

Numerous intentional and unintentional species introductions have occurred in the Columbia River Basin (Sytsma et al. 2004). Effects on white sturgeon may include a decrease in prey

value (**lipid** content, **metabolic energy**, etc.) associated with the replacement of native/historic forage by non-native prey species and/or through direct competition for resources between native and non-native species that reduce the abundance or productivity of native species. Although non-native Asian clams and American shad now make up a considerable component of the white sturgeon diet in the lower Columbia River; little is known regarding the food value of these species compared to native prey items. Unlike numbers of native forage fish such as eulachon and lampreys, numbers of American shad, a member of the herring family introduced to the Pacific Coast in the 1800s, have remained high within the Columbia Basin. Passage of adult American shad at Bonneville Dam has surpassed 1 million individuals every year since 1988 (FPC 2010b) and peaked in 2005 at more than 5 million (Figure 16).



**Figure 16.** Upstream adult American shad passage (in thousands) at Bonneville Dam 2002 – 2008.

However, the effects of this non-native species as a potential prey base are unknown, because how American shad compare to eulachon and lampreys as prey for adult white sturgeon is unknown. Additionally, many species of herring are known to have high tissue concentrations of **thiaminase**, a naturally occurring, thiamine (vitamin B1)-degrading enzyme (Tillitt et al. 2005; Fitzsimons et al. 2005; Honeyfield et al. 2007). Fish whose diets are primarily comprised of thiaminase-rich prey may exhibit reproductive failure (Tillitt et al. 2005; Honeyfield et al. 2007; Madenjian et al. 2008). Thiaminase activity in both adult and juvenile American shad has recently been shown to be similar to other herrings (Tillitt et al. 2008). The effects of a thiaminase-rich diet on white sturgeon populations are unknown, though they may be minimized by the white sturgeon life history strategy. There appear to be two main factors regarding susceptibility to thiamine deficiency in predatory fish species: diet diversity and fertilization to hatching time (D. Tillitt, USGS, personal communication). Fish that have a homogeneous

**clupeid**-rich diet, such as great lakes salmonids or Atlantic salmon *Salmo salar*, are more likely to suffer thiamine deficiency related reproductive failures than those that do not (Wolgamood et al. 2005; Tillitt et al. 2005). Adult white sturgeon may feed actively on American shad, but this feeding is seasonal and at other times of the year they diversify their prey base. The amount of time that fish must rely on maternally-derived nutrition may also relate to susceptibility to thiamine deficiency. Larval white sturgeon are hatched and actively feeding within 19 – 26 days after spawning; a shorter time period than many salmonines that exhibit thiamine-related reproductive failure (Tillitt et al. 2005; Honeyfield et al. 2007; Madenjian et al. 2008).

Some introduced species, such as American shad, may interact with juvenile sturgeon either competing directly for food resources or preying on them as food resources. In Atlantic slope rivers American shad are known to feed heavily on **chironomid** larvae (Ross et al. 1997), and have also been found with fish and fish larvae in their digestive tracts (Walburg 1957). Chironomids are small winged insects and their larval stage resides on river bottoms and is prey item used by white sturgeon (Semakula and Larkin 1968; McCabe et al. 1993). It is unknown what affects inter-specific competition may have on white sturgeon in the lower Columbia River.

## **10.9 Total Mortality**

Total mortality of sub-adult and adult life-stages of white sturgeon is composed of fishing mortality, other human influenced sources of mortality and natural sources of mortality. At this point total mortality is unknown and its components are poorly understood. Fishing mortality includes actual exploitation rate of retention fisheries, incidental and delayed recreational and commercial fishing mortality and illegal harvest. Other human influenced sources of mortality may include: incidental hydro-system mortality and mortality associated with commercial river navigation and recreational boating. Natural sources of mortality may include disease, predation, and aging processes. Some potential sources of mortality, such as pollutants, contaminants, and altered predation levels may fall into both human influenced and natural sources of mortality.

### **10.9.1 Exploitation Rate**

There is currently an adequate system in place to account for actual removals associated with recreational and commercial harvest; however, the actual exploitation rate on lower Columbia River white sturgeon is currently much less well understood. This lack of understanding is primarily due to uncertainties surrounding the population estimates, detailed in Section 10.1, uncertainties surrounding delayed mortality associated with released fish, uncertainties associated with removals outside the lower Columbia River, and uncertainties associated with tags that are shed prior to harvest.

### **10.9.2 Incidental Mortality Related to fishing**

The magnitude of lower Columbia River white sturgeon indirect mortality related to recreational and commercial fishing activities is unknown, though some indirect mortality likely occurs. Carcass surveys conducted by WDFW routinely find deceased white sturgeon with fishing hooks embedded internally or external scars in the tongue, mouth, or gills (WDFW unpublished data). Gill net scars have been noted on deceased sturgeon, though only once since 2004; it should be noted that the carcass surveys occur upstream of RM 128 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 do exhibit a hormonal (**plasma cortisol**) stress response when they are handled by commercial or

recreational fishing gear (ODFW, unpublished data). Furthermore, recent research has found a strong positive correlation between “play time” and stress hormones present in white sturgeon blood and that white sturgeon captured by hook and line exhibit higher concentrations of blood plasma cortisol than those captured via set-line (Webb and Doroshov 2011). Cumulative stress, the kind associated with repeated catch and release events, has been shown to cause delayed mortality and reproductive failure in other fish species (Schreck et al. 2001; Schreck 2010); though in white sturgeon a link between handling stress related to angling targeted at over-size sturgeon and reduced reproductive success has not yet been documented. A strong positive correlation between play time and stress hormones does exist in lower Columbia River white sturgeon, however, there is a lot of variability surrounding these relationships – 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).

### **10.9.3 Illegal Harvest**

Although illegal harvest (poaching) of white sturgeon in the lower Columbia River is almost certainly an ongoing problem (see Section 9.2.5), the extent and magnitude of these removals is currently not completely quantified. The OSP currently enforce white sturgeon regulations and in 2008 and 2009 reported 25 and 48 illegally harvested white sturgeon in the lower Columbia River; however because of staffing and enforcement limitations this should be considered the minimum number illegally harvested – considering past poaching rings (Cohen 1997), and the monetary value of white sturgeon and their row, the actual number is likely considerably higher.

### **10.9.4 Incidental Hydro-System Mortality**

Incidental hydro-system white sturgeon mortality events, including draft tube dewatering, bringing units on-line, and turbine blade strikes associated with are known to occur (see Section 9.2.6). However, the actual magnitude of these events, especially the start-up of offline units which often occur at night, is currently unknown (B. Hausmann, USACE, personal communication).

### **10.9.5 Commercial River Navigation and Recreational Boating Mortality**

Whether through direct propeller strikes or through chronic stress associated with pressure waves and noise, there is likely some white sturgeon mortality associated with commercial and recreational boating in the study reach. Boat strikes have been noted as a source of mortality to Atlantic sturgeon *Acipenser oxyrinchus* in the Delaware River (Simpson and Fox 2007; Simpson and Fox 2009). Results provided by Simpson and Fox (2007, 2009) indicate that Atlantic sturgeon (juveniles and adults) often inhabit main channel habitats, and white sturgeon exhibit similar behavior (Parsley et al. 2008). Large commercial ships often have limited bottom clearance (<6.5 feet) when transiting the Columbia River (Columbia River Channel Coalition 2010). These two facts increase the probability that negative interactions with boats will occur.

### **10.9.6 Pinniped Predation Mortality**

Pinnipeds have been documented predating on sturgeons on both seaboard of North America (Fernandes 2008; Stansell et al. 2010), and as mentioned in Section 9.1.1, pinniped predation on white sturgeon in the lower Columbia River is thought to be a significant source of direct mortality (Tackley et al. 2008b). However, it is unclear how current levels compare to historic

levels, current belief is that it is elevated over that level. The actual magnitude of pinniped predation on lower Columbia River white sturgeon is unknown, though it is higher than the 1,710 fish estimate for the area immediately below Bonneville Dam (Stansell et al. 2009). The estimate provided by Stansell et al. (2010) is a minimum estimate as the standardized observations start after known predation events have already occurred and observations are limited to the vicinity of Bonneville Dam leaving approximately 143 miles of river unmonitored. Pinniped predation on white sturgeon has been documented throughout the lower 143 miles of the river (ODFW, unpublished data), and recent attempts to quantify this have generated an estimate of 6,700 that is expected to increase to 10,600 by 2014 (see Appendix B). Additionally, a comprehensive investigation of Columbia River pinniped bioenergetics has not been conducted. To thoroughly understand the potential impacts of pinniped predation on this white sturgeon population segment their bioenergetics requirements need to be considered. Furthermore, the cumulative effects that even unsuccessful predation events may have on white sturgeon are unknown. Based on the number of sea lion scars recently noted on adult white sturgeon (M. Webb, USFWS, personal communication), it is plausible that white sturgeon could exhibit a stress response as a result of chasing and avoidance behavior from sea lions similar to that attributed to commercial and recreational fishing, i.e. potential adverse effects on spawning success (Schreck 2010).

### **10.9.7 Contaminant Effect on Productivity**

White sturgeon can absorb a variety of pollutants and contaminants through direct contact or bioaccumulation through the food chain. However, the magnitude and exact effects on white sturgeon productivity of these various chemicals and metals are unknown.

#### *10.9.7.1 Chlorinated Pesticides and PCBs*

Endocrine disruptors 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 of their life history, white sturgeon are susceptible to bioaccumulation of environmental pollutants and contaminants, and there may be a link between contaminants and reduced growth and reproduction (Foster et al. 2001a, 2001b; Webb et al. 2006, Feist et al. 2005); however, to date, all studies investigating the link between these pollutants and adverse effects on white sturgeon have been correlative in nature and exact affects have not been determined

#### *10.9.7.2 Heavy-metals*

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

### **10.9.8 Natural Mortality**

An estimate of natural mortality has not been generated for lower Columbia River white sturgeon since the early 1990s (DeVore et al. 1995). Calculating a natural mortality estimate is problematic. There are uncertainties surrounding the accuracy of aging techniques (Rien and Beamesderfer 1994), which casts a shadow on traditional catch curve methods. Furthermore, the high percentage of tag loss (71% after 48 months; DeVore et al. 1995) associated with spaghetti

tags makes survival estimates based on year to year mark recaptures using this tagging method variable and unreliable.

## **Section 11 Conservation and Management Recommendations**

### ***11.1 Recommended Monitoring and Evaluation Needed to Assess the White Sturgeon Population in Relation to Desired and Conservation Status***

*Recommended Monitoring and Evaluation* are those actions needed to a) characterize current population status, capturing the temporal and spatial variability in the metrics of interest, and b) measuring a particular metric at regular time and space intervals to assess its long term trend and progress towards the desired or conservation status. To be sure that research monitoring and evaluation activities are carried out in the most effective, informative, and efficient way possible a detailed monitoring plan needs to be developed. This monitoring plan needs to be developed in consultation with survey sampling statisticians to ensure the statistical robustness of any implemented sampling regimes. The results of any implemented sampling should be documented with a formalized reporting process.

#### **11.1.1 Abundance**

*Description* – The desired abundance status is to achieve annual abundance of sub-adult and adult white sturgeon that eventually exceeds approximately 368,000 and 16,250 individuals respectively. The conservation status threshold is 31,000 and 3,900 respectively for sub-adults and adults.

*Recommended Monitoring and Evaluation*

- Conduct white sturgeon stock assessments, using non-size selective gear (e.g., set-lines), in the lower Columbia River annually to monitor size distribution, growth, condition and abundance within this reach; continue use of current population indexing tools, e.g., catch rate information.
- Conduct periodic white sturgeon stock assessments (every 5 to 10 years) in areas outside of lower Columbia River waters downstream of Bonneville Dam, such as Tillamook (OR) and Willapa (WA) bays, where white sturgeon are known to congregate, using a combination of size selective and non-size selective gear.
- Conduct recreational and commercial fisheries monitoring activities for weight of evidence materials used to evaluate current status as well as trends over time of the lower Columbia River white sturgeon population segment. Information collected should include, but not necessarily be limited to: effort, number of fish of a given size caught and released, average size of catch, and tag recoveries.

### 11.1.2 Distribution

*Description* – The desired distribution status is that lower Columbia River white sturgeon are distributed throughout and have access to all habitat segments downstream of Bonneville Dam including the mainstem lower Columbia River and its estuary, the mainstem Willamette River including reaches both downstream and upstream of Willamette Falls, and in coastal bays, estuaries, and rivers. The conservation status threshold is that white sturgeon are determined to be locally absent from one or more of the habitat segments throughout their range.

#### *Recommended Monitoring and Evaluation*

- Monitor white sturgeon populations throughout those lower Columbia River habitats downstream of Bonneville Dam, including the Willamette River and evaluate the extent and distribution of the population using fisheries and fisheries-independent monitoring techniques.

### 11.1.3 Diversity

*Description* – The desired diversity status is for the average allelic frequency for multi-year cohorts of white sturgeon at 14 standardized loci to be  $\geq 235$ . The conservation status threshold is that the allelic frequency for multi-year cohorts of white sturgeon at those same 14 standardized loci is  $< 140$ .

#### *Recommended Monitoring and Evaluation*

- Monitor the genetic diversity in the lower Columbia River white sturgeon population to evaluate any changes in population parameters caused by either population expansion or increased mortality due to impoundment and other anthropogenic disturbances. Because of the longevity of white sturgeon, genetic diversity monitoring programs may be conducted on a decadal basis unless a drastic change in the lower Columbia River white sturgeon population size is suspected. Random sampling of 100 to 150 lower Columbia River white sturgeon (irrespective of age class) would provide the most accurate representation of extant genetic diversity at any particular time; samples should be taken throughout population segment range, including the Oregon Coast and the Willamette River.
- Evaluate potential spatial stock structures by taking samples and examining diversity throughout the lower Columbia River white sturgeon population segment.
- Further develop the ability to estimate spawner contributions to wild populations by improving analysis techniques, and improve fish relatedness determination methods to the point where unrelated, half-sibling, and full-sibling individuals can be easily and accurately identified.

### 11.1.4 Productivity

*Description* – There are two productivity metrics for which desired status has been set. The desired status thresholds for these metrics are, the overall 10 year average catch per net of age-0 white sturgeon captured during standard indexing activities should be  $\geq 5.66$ , and the length frequency distribution of the lower Columbia River white sturgeon population is distributed in a balance fashion, i.e., 95% juveniles, 4.5% sub-adults, and 0.5% adults. The conservation status thresholds for each of these metrics are no detectable age-0 white sturgeon recruitment for 5 or

more years in a row or more, and a skewed length frequency distribution that indicates that 60% or less of the population is composed of juvenile white sturgeon.

#### *Recommended Monitoring and Evaluation*

- Index annual levels of, and variation in, white sturgeon recruitment in the free-flowing Columbia River downstream of Bonneville Dam. Correlate age-0 indexing data to juvenile abundance estimates and to estimated egg-to-age-1 survival rates.
- Evaluate use of early life history sampling (e.g., egg mats and larval tows) to index white sturgeon productivity in the lower Columbia and Willamette Rivers and potentially compare productivity of each.
- Using genetic tools estimate spawner contributions to juvenile white sturgeon multi-year cohorts on a decadal basis.
- Monitor spawning and rearing conditions and available habitat via water releases at Bonneville Dam and spawning periodicity through mark and recapture maturity work; ensure spawning success and recruitment to age 1 by optimizing water releases and through continued time and area management of sport and commercial fisheries in the Columbia River.
- Conduct white sturgeon stock assessments, of sufficient mark group magnitude and geographic scope, in the lower Columbia River annually to monitor size distribution, growth, condition and abundance within this reach; continue use of current population indexing tools, e.g., catch rate information.
- Conduct periodic white sturgeon stock assessments, of sufficient effort and geographic scope, (every 5 years) in areas outside the lower Columbia River, such as Tillamook (OR) and Willapa (WA) bays, where white sturgeon are known to congregate.
- Determine the relative contribution of Willamette River spawning white sturgeon to population productivity and abundance.

### **11.1.5 Habitat**

*Description* – There are three habitat metrics for which desired status has been determined. The desired status for these metrics are for spawning habitat to be  $\geq 56.8$  of temperature conditioned weighted useable area, for age-0 rearing habitat to be  $\geq 22,240$  acres of weighted usable area, and for juvenile white sturgeon rearing habitat to be  $\geq 30,888$  acres of weighted usable area. The respective conservation status thresholds for these three metrics are  $< 51.4$  for ten or more consecutive years,  $< 11,120$  acres, and  $< 15,444$  acres.

#### *Recommended Monitoring and Evaluation*

- Identify, characterize, catalogue, and monitor spatial and seasonal white sturgeon spawning and rearing habitats throughout those lower Columbia River waters downstream of Bonneville Dam, including those waters outside the Columbia River mainstem (e.g., Willamette River upstream of Willamette Falls, coastal estuaries, etc.).

### **11.1.6 Persistence**

*Description* – The desired persistence status is that average predicted probability of persistence is  $\geq 0.99$ . The conservation status persistence threshold is that average predicted probability of persistence is  $< 0.95$ .

#### *Recommended Monitoring and Evaluation*

- Conduct white sturgeon stock assessments in the lower Columbia River annually to monitor size distribution, growth, condition and abundance within this reach; continue use of current population indexing tools, e.g., catch rate information.
- Conduct periodic white sturgeon stock assessments (every 5 years) in areas within those lower Columbia River waters downstream of Bonneville Dam, such as Tillamook (OR) and Willapa (WA) bays, where white sturgeon are known to congregate.
- Qualitatively evaluate persistence by monitoring the status of the five other primary biological attributes listed above.
- Fully vet through a peer reviewed process the recently developed ODFW population dynamics based PVA model that will be used for assessing current status in relation to the desired and conservation status benchmarks.
- Evaluate the utility of modifying the individual based model approach used in the Snake River white sturgeon PVA model (Jager et al. 2000) as an alternative persistence modeling approach.

### **11.1.7 Growth and Condition**

*Description* – There are two growth and condition metrics for which desired status has been determined. The desired status for these metrics are an average annual sub-adult white sturgeon growth of  $\geq 3.2$  inches per year, and an annual average sub-adult white sturgeon relative weight of  $\geq 100$ . The conservation status thresholds for these two metrics are an average annual sub-adult white sturgeon growth of  $< 1.6$  inches, and an annual average sub-adult white sturgeon relative weight of  $< 90$ .

#### *Recommended Monitoring and Evaluation*

- Conduct white sturgeon stock assessments in the lower Columbia River annually to monitor size distribution, growth, condition and abundance within this reach; continue use of current population indexing tools, e.g., catch rate information.
- Evaluate correlations between growth and condition and environmental variables using multivariate analyses.

### **11.1.8 Natural Mortality and Survival**

*Description* – There are two mortality and survival metrics for which desired status has been determined. The desired status for these metrics are that the average annual estimated natural mortality rate of sub-adult white sturgeon should be  $\leq 9\%$  and the estimated average annual survival rate of adult white sturgeon should be  $94\%$ . The conservation status thresholds for these same metrics are that annual estimated natural mortality of sub-adult white sturgeon is  $\geq 21.3\%$  and the estimated annual survival rate of adult white sturgeon is  $\leq 74\%$ .

#### *Recommended Monitoring and Evaluation*

- Conduct white sturgeon stock assessments in the lower Columbia River annually to monitor size distribution, growth, condition and abundance within this reach; continue use of current population indexing tools, e.g., catch rate information.
- Assess the current natural mortality and survival levels and evaluate the total mortality level for lower Columbia River white sturgeon.

### **11.1.9 Fishing Mortality and Harvest**

*Description* – There is one fishing mortality and harvest metrics for which desired status has been determined. The desired status for this metric is that 38 – 54 inch FL white sturgeon should be sustainably managed at an average annual estimated exploitation rate of 16. Exploitation rates are too high and will lead to the eventual modeled collapse of the fishery if they are sustained at  $\geq 29\%$  for the duration of the model. Therefore fishing mortality will be in conservation status the three year average annual estimated exploitation rate of 38 – 54 inch FL white sturgeon is  $\geq 29\%$ .

#### *Recommended Monitoring and Evaluation*

- Conduct recreational and commercial fisheries monitoring activities for weight of evidence materials used to evaluate current status as well as trends over time of the lower Columbia River white sturgeon population segment. Information collected should include, but not necessarily be limited to, effort, number of fish of a given size caught and released, average size of catch, and tag recoveries.
- Conduct white sturgeon stock assessments in the lower Columbia River annually to monitor size distribution, growth, condition and abundance within this reach; continue use of current population indexing tools, e.g., catch rate information.
- Assess the current fishing mortality levels and evaluate the total mortality level for lower Columbia River white sturgeon.

### **11.2 Recommended Management Strategies and Actions Targeting Critical Constraints, Limiting Factors, and Threats**

*Recommended Management Actions* are specific measures designed to remedy critical constraints, limiting factors, and/or threats. Recommended actions may target one or more critical constraint, limiting factor, and/or threat. *Action Effectiveness Standards* provide a benchmark that the performance of recommended management actions may be measured against. *Recommended Research, Monitoring, and Evaluation* are those activities needed to a) determine whether an action has been implemented, b) determine whether an implemented action is achieving its desired outcome, and/or c) otherwise inform regional managers and scientists with regard to a potential limiting factor. The results of any implemented management action or monitoring and evaluation program should be documented annually with a formalized reporting process.

Following implementation of a Recommended Management Action, and evaluation of the Action against an Action Effectiveness Standard through Monitoring and Evaluation, it is expected that adaptive management and modification of the original Recommended Management Action will occur through a feedback loop if indicated by Monitoring and Evaluation results. To be sure that adaptive management is carried out in the most effective, way possible a detailed adaptive management plan needs to be developed. This should include (1) a series of explicit expectations, models and indicators to evaluate status and trends and (2) explicit loops from monitoring results back to key trigger points. Part of this plan will be a detailed implementation framework for how and when actions and measures should be carried out.

## 11.2.1 Biotic Factors

### 11.2.1.1 Marine Mammal Predation

*Description* – Although predation by Steller and California sea lions on white sturgeon below Bonneville Dam has increased sharply in recent years (Tackley et al. 2008a; Stansell et al. 2009); the exact extent and magnitude of losses and effects on white sturgeon population productivity are poorly understood. However, consumption rates appear to be higher in the Bonneville Dam tailrace than in the rest of the lower Columbia River, if pinnipeds could be removed from this area a decrease in river-wide predation should occur.

*Management Strategy* – Minimize pinniped predation related mortality on lower Columbia River white sturgeon populations.

#### *Recommended Management Actions*

- Cooperatively manage marine mammals to minimize predation of white sturgeon, especially adult white sturgeon, downstream of Bonneville Dam, including the lower Willamette River, by dispersing congregations and redistributing as many pinnipeds as possible to areas outside of the current angling sanctuary, i.e., that area between Skamania Island (RM 136) and Bonneville Dam (RM 145); management may include the removal of problem animals.
- Assess *river-wide* white sturgeon losses to pinniped predation.

#### *Action Effectiveness Standards*

- Our PVA modeling exercises indicate that if all pinnipeds were removed from the current angling sanctuary could reduce white sturgeon pinniped related mortality by up to 75%, the recommended management action should result in a substantial measurable decrease in predation.

#### *Recommended Research, Monitoring, and Evaluation*

- Monitor marine mammal predation on white sturgeon in the vicinity of Bonneville Dam and in the remainder of those lower Columbia River waters downstream of Bonneville Dam in a temporally and spatially expanded monitoring program.
- Assess the efficacy of marine mammal hazing and recommended management efforts.
- Using the temporally and spatially expanded monitoring program, identify and assess the spatial and temporal distribution of pinnipeds in the Columbia River from the river mouth upstream to Bonneville Dam and in the Willamette River to Willamette Falls.
- Investigate feeding ecology and bioenergetics, including diel diet patterns and physiological restrictions (e.g., can they eat under water), of pinnipeds in the lower Columbia River.
- Quantify the magnitude and extent of marine mammal predation on white sturgeon populations in the entire Columbia River from the river mouth upstream to Bonneville Dam.
- Model the impact of pinniped predation and pinniped removals on lower Columbia River white sturgeon population dynamics.
- Investigate novel sea lion hazing techniques, compare effectiveness of novel techniques to currently identified and implemented techniques, and explore the feasibility of public use.

### 11.2.1.2 Piscine Predation

*Description* – White sturgeon, at a variety of life stages, are preyed on by other fish in freshwater and marine environments.

*Management Strategy* – Minimize the impacts of piscine predation related mortality on lower Columbia River white sturgeon populations.

#### *Recommended Management Actions*

- Operate the FCRPS to minimize predation on white sturgeon early life history stages by native and non-native predators. River flows to accomplish this would likely consist of the same flows identified in Section 11.2.2.3 for spawning. These flows would be consistent with juvenile salmonid passage and aggressive non-breach hydrosystem operations.

#### *Action Effectiveness Standards*

- The FCRPS is being operated, consistent with aggressive non-breach, to provide and maintain spawning flows that also disperse eggs over a wide area to reduce the efficiency of predation and predation related mortality on the early life history stages of white sturgeon.

#### *Recommended Research, Monitoring, and Evaluation*

- Monitor piscine predation on the early life history stages of white sturgeon in the Bonneville Dam tailrace.
- Evaluate operational strategies that are designed to minimize piscine predation.
- Assess the magnitude of marine predation (e.g. seven-gill sharks) on white sturgeon.
- Investigate effects of potential predation on white sturgeon by non-native piscine predators in the lower Columbia River, e.g., American shad, walleye, and black basses *Micropterus spp.*

## 11.2.2 Abiotic Factors

### 11.2.2.1 Habitat Quality and Quantity

*Description* – Quantity and quality of main channel, off channel, estuarine, and riparian white sturgeon habitat in the lower Columbia River has been impacted through a variety of human disturbance factors.

*Management Strategy* – Protect and restore high quality main channel, off channel, estuarine, and riparian white sturgeon habitat in the lower Columbia River and adjacent waters, including the Willamette River and coastal bays, estuaries and rivers.

#### *Recommended Management Actions*

- Operate the Federal Columbia River Power System (FCRPS) to provide white sturgeon spawning and rearing habitat downstream of Bonneville Dam in sufficient quantity and quality to maintain white sturgeon population productivity. Operations should target physical conditions that maximize or optimize the quantity, quality, and distribution of spawning and/or rearing habitat as well as adjacent riparian habitat.
- Work with partners to continue restoration of floodplain and estuary rearing habitat.

- Comment on in-water work and development permits in coordination with appropriate state and federal agencies; recommend measures to ensure the negative effect of this work on white sturgeon spawning and rearing habitat in those lower Columbia River waters downstream of Bonneville Dam is minimized, avoided, or mitigated for.
- Fund additional law enforcement personnel to enforce current habitat protection laws/regulations. Additional law enforcement positions could also be utilized to enforce current water quality laws/regulations as outlined in section 11.2.2.4 and laws/regulations affecting illegal harvest as outlined in section 11.2.2.5.

#### *Action Effectiveness Standards*

- The FCRPS is being operated to provide a minimum of 56.8 units of temperature conditioned weighted useable area of white sturgeon spawning habitat downstream of Bonneville Dam until a spatially explicit analysis can be conducted to evaluate how spawning habitat quantity and quality vary as a function of spillway and powerhouse discharges. Following completion of this analysis, a new standard may be developed.
- In-water work and development will not cause a net loss of high quality spawning or rearing habitat as defined by Parsley and Beckman (1994).
- Compliance with existing habitat laws/regulations, as measured by the ratio of habitat enforcement violations to habitat enforcement levels, is higher than 2009 levels.

#### *Recommended Research, Monitoring, and Evaluation*

- Identify, characterize, catalogue, and monitor spatial and seasonal white sturgeon spawning and rearing habitats throughout those lower Columbia River waters downstream of Bonneville Dam, including the Willamette River.
- Investigate estuarine, tidally influenced freshwater and off-channel shallow water habitat usage by juvenile and sub-adult white sturgeon.
- Evaluate the effect of the proposed construction (e.g. spill training wall) in the tailrace of Bonneville Dam on white sturgeon spawning habitat quantity, quality, and distribution.
- Determine if there is a flow-spawning relationship for white sturgeon in the Willamette River; if such a relationship exists, recommend operations of Willamette River System hydro-electric and flood control projects to ensure spawning habitat in the Willamette River.
- Identify and assess seasonal and spatial white sturgeon habitat usage of nearshore (to 600 feet) marine habitats and migration corridors.
- Model the impact of past spawning and rearing habitat losses on lower Columbia River white sturgeon population dynamics.
- Develop more advanced habitat modeling tools to better quantify the amount of spawning and rearing habitat available in those lower Columbia River waters downstream of Bonneville Dam.
- Monitor habitat enforcement efforts to determine if there is a change in the number of violations, as they relate to the 2009 enforcement effort level.

### **11.2.2.2 Habitat Fragmentation**

*Description* – River fragmentation, due to construction of the FCRPS, reduces the quality and quantity of habitat, alters migration patterns, and may impose unidirectional (downstream) gene flow on lower Columbia River white sturgeon.

*Management Strategy* – Restore Columbia River connectivity to promote healthy lower Columbia River white sturgeon populations.

*Recommended Management Actions*

- Operate the FCRPS to minimize white sturgeon habitat fragmentation downstream of, and allow for white sturgeon upstream and downstream passage at Bonneville Dam. Habitat fragmentation downstream can be minimized by limiting power peaking and load following operations. Investigate potential passage options at Bonneville Dam, e.g., renovating the existing fish lift, retrofitting fish ladders, or potentially making modifications to the navigation lock.
- Restore the connectivity between rearing habitats (main channel, side channels, oxbows, and tidewaters) in the floodplain and estuary.

*Action Effectiveness Standards*

- White sturgeon upstream and downstream passage, as measured at existing fish ladders at Bonneville Dam is not less than the previously estimated annual average (1986 -1991) passage estimate of  $36 \pm 6.5$  (mean  $\pm$  SE; Warren and Beckman 1993).
- White sturgeon use of restored/reconnected rearing habitats is documented; white sturgeon are not stranded in these habitats by the tidal cycle or system-caused reductions in stream flow.

*Recommended Research, Monitoring, and Evaluation*

- Monitor white sturgeon passage at Bonneville Dam and Willamette Falls fish passage facilities; assess residence time in fishways.
- Assess size-specific upstream and downstream passage and survival through non-fishway passage routes (e.g., navigation locks at Bonneville Dam and Willamette Falls, turbine passage, juvenile salmon bypass systems).
- Identify and understand the advantages, disadvantages, and possible obligations to providing upstream and downstream white sturgeon passage at Bonneville Dam.
- Conduct studies to understand how fragmentation of wintering and spawning habitat downstream from Bonneville Dam caused by tailrace construction (e.g., a spillway training wall) affects adult sturgeon movements and the quality and quantity of spawning habitat.
- Identify and assess potential sources of habitat fragmentation and fragmented habitats within those lower Columbia River waters downstream of Bonneville Dam. Specific assessments should include, but not be limited to, fragmentation resulting from tides and fragmentation resulting from 1) daily hydropower operations and 2) long-term changes in fragmentation resulting from shifting the flow regime for hydropower operation.
- Monitor white sturgeon usage of rearing habitats restored in the floodplain and estuary, and the potential for stranding in these habitats.

### **11.2.2.3 Flow and Flow Variation**

*Description* – The lower Columbia River hydrograph has been dramatically altered by the development of the FCRPS and Canadian storage projects; spring freshet flows have been reduced by about 50%, and winter flows have increased about 30%. Hourly and daily stream flow variation from power production (load following) reduces the quality and stability of white

sturgeon habitats. Providing continuous spill will maintain a spawning area downstream from the Bonneville Dam spillway, thus ensuring presence of this spawning area.

*Management Strategy* – Provide and maintain consistent flows and restore historic Columbia River hydrograph, when possible, to promote healthy lower Columbia River white sturgeon populations.

#### *Recommended Management Actions*

- Configure and operate the Bonneville Dam power houses and spillway to maximize the amount of high quality spawning habitat downstream from the dam during the time period when peak spawning occurs (i.e. when temperatures are between 54 – 61 °F). The FCRPS Biological Opinion (NMFS 2008) requires 100 kcfs of spill, or spill to the gas cap during the spring sturgeon spawning season. Spill should be maintained at 100 kcfs as called for in the Biological Opinion, with some amount of variation around this specified level to control total dissolved gas.
- Evaluate spawning habitat in the transition zones ([a] between Bradford and Cascade Islands, and Tanner Creek; [b] downstream from Tanner Creek) downstream from Bonneville Dam to determine how a range of operations at the dam affect hydraulics in the transition zones and the resulting suitability of spawning habitat.
- Develop a plan to provide constant flow, i.e., **flat-load**, one powerhouse at a continuous discharge that produces high quality, stable sturgeon spawning habitat, while following load at the other powerhouse, after determining the suitability of the hydraulics downstream from each power house and describing how that suitability changes across a range of stream flows. There may be some flexibility to differentially load the two Bonneville Dam power houses in order to minimize variation and maximize stability of conditions downstream from one of the locations.

#### *Action Effectiveness Standards*

- April through June spill is being maintained at a continuous 100 kcfs flow level with variation required to control total dissolved gas levels.
- Following an analysis of hydraulic conditions and spawning habitat suitability associated with a range of flows through power houses 1 and 2, recommendations are developed to flat-load one power house to provide stable spawning habitat, while following load with the other power house.
- Following an analysis of hydraulic conditions and spawning habitat suitability associated with a range of flows in the transition zones, a new set of flow recommendations is developed, if appropriate, that integrates the effect of Bonneville operations on potential spawning habitat below the spillway, power houses, and in the transition zones.

#### *Recommended Research, Monitoring, and Evaluation*

- Monitor hourly spill and power house discharge levels at Bonneville Dam.
- Conduct the necessary research to determine the flow configurations for Recommended Management Actions and Action Effectiveness Standards.
- Identify how flow routing at Bonneville Dam affects spawning success below the spillway, power houses, and transition zones, egg deposition, dispersal of free swimming embryos, and access to rearing habitats.

- Assess white sturgeon habitat given the three tailraces and partitioning of flows through the powerhouses and spillway downstream from Bonneville Dam.
- Determine the effects of power peaking operations and load following at Bonneville Dam on white sturgeon spawning behavior and success.
- Investigate riparian and off-channel shallow water habitat usage by white sturgeon early life history stages in the Ives and Pierce Island complex downstream of Bonneville Dam and determine potential effects of daily and hourly flow variations associated with power peaking on survival of these early life history stages.

#### **11.2.2.4 Water Quality**

*Description* – Water quality, e.g., temperature, low turbidity, dissolved gasses, and/or pollutants and contaminants, may act as a factor limiting lower Columbia River white sturgeon productivity. A variety of human actions, including construction of the FCRPS and industrial pollution may be contributing to water quality issues in this river reach.

*Management Strategy* – Maintain water quality in the lower Columbia River to promote healthy lower Columbia River white sturgeon populations and ecosystems.

##### *Recommended Management Actions*

- Operate FCRPS to ensure water temperatures and dissolved gas supersaturation levels are within white sturgeon spawning, incubation, and early life stage development and dispersal criteria downstream of Bonneville Dam.
- Fund additional law enforcement personnel to enforce current water quality protection laws/regulations. Additional law enforcement positions could also be utilized to enforce current habitat quality laws/regulations as outlined in section 11.2.2.1 and laws/regulations affecting illegal harvest as outlined in section 11.2.2.5.

##### *Action Effectiveness Standards*

- Temperatures ranging between 50 – 64 °F and dissolved gas levels less than 110% occur downstream of Bonneville Dam during the April – June white sturgeon spawning timeframe.
- Compliance with existing habitat laws/regulations, as measured by the ratio of water quality enforcement violations to water quality enforcement levels, is higher than 2009 levels.

##### *Recommended Research, Monitoring, and Evaluation*

- Monitor water temperatures and total dissolved gas levels in the Bonneville Dam tailrace.
- Identify and assess the impacts of FCRPS operations on water temperatures in the lower Columbia River.
- Identify the effects of low turbidity on white sturgeon recruitment in the lower Columbia River.
- Identify the effects of total dissolved gasses on white sturgeon survival in the lower Columbia River.
- Determine the spatial and temporal distribution of white sturgeon early life stages (egg through dispersal and larval settlement) downstream from Bonneville Dam.
- Implement cause and effect studies to determine if pollutants and contaminants affect white sturgeon survival and spawning success in the lower Columbia River.

- Model the effects of changes in a variety of water quality parameters on lower Columbia River white sturgeon population dynamics.
- Conduct “dose-response” studies to resolve issues surrounding toxins of concern by identifying the specific toxin and contaminant effects on white sturgeon survival and spawning success.
- Monitor water quality enforcement efforts to determine if there is a change in the number of violations, as they relate to the 2009 enforcement effort level.

### **11.2.2.5 Fishing Effects**

*Description* – Direct and indirect white sturgeon mortality associated with illegal and legal fisheries from the lower Columbia River has the potential to reduce the numbers of white sturgeon reaching spawning sizes, thereby negatively affecting subsequent white sturgeon generations and fishing opportunities.

*Management Strategy* – Guard against over-utilization and manage lower Columbia River white sturgeon populations to provide ecological, socio-economic, and cultural benefits now and into the future.

#### *Recommended Management Actions*

- In consultation with the appropriate state agencies and management entities, and to facilitate reaching desired status, fund intensive white sturgeon fishery management including: the identification of annual sustainable recreational and commercial harvest levels through population simulation that accounts for variable natural production, growth rate, and abundance; and conduct harvest monitoring that enables active in-season management to attain pre-determined escapement levels to the adult population.
- Recommend implementing annual harvest levels based on an annual sustainable exploitation rate of 16% and estimated population abundances of 38 – 54 inch FL white sturgeon; continue to model population responses to implemented fisheries.
- Continue the use of exploitation rate fishery management buffers to shield lower Columbia River white sturgeon populations from uncertainties associated with constraints, limiting factors and threats, and critical unknowns and data gaps. The white sturgeon population in the mainstem lower Columbia River is currently being managed to modeled sustainable exploitation rate of 22.5% exploitation rate on 38 – 54 inch FL. This plan is recommending a 16% exploitation rate on the same size fish to account for uncertainties associated with pinniped predation and recruitment. This management buffer is deliberate, with the goal of lowering exploitation rates from predetermined targets to reduce potential risks to the white sturgeon population (Fieberg 2004).
- Implement educational and angler awareness programs to inform the public of the consequences of over-harvest of long-lived white sturgeon.
- Fund additional law enforcement personnel to enforce current laws/regulations that protect lower Columbia River white sturgeon. Additional law enforcement positions could also be utilized to enforce current habitat quality laws/regulations as outlined in section 11.2.2.1 and laws/regulations affecting water quality as outlined in section 11.2.2.4.

#### *Action Effectiveness Standards*

- Fishery exploitation rates on lower Columbia River white sturgeon are 16% on 38 – 54 inch FL fish, the modeled exploitation rate that builds the population while safeguarding from uncertainties and maintaining viable fisheries, and s (see Appendix B).
- Public awareness of the value of white sturgeon fisheries is increased.
- Compliance with existing angling and commercial laws/regulations, as measured by the ratio of fishing enforcement violations to fishing enforcement levels, is higher than 2009 levels.

*Recommended Research, Monitoring, and Evaluation*

- Use population simulation with updated parameter estimates for survival by size class, age at length, age at maturity, spawning frequency or proportion that contribute to spawning, in order to refine the currently accepted estimate of the OSY exploitation rate for the lower Columbia River white sturgeon population.
- Monitor set and implemented white sturgeon recreational and commercial fisheries, including catch and release recreational fisheries.
- Conduct mark-recapture survival analyses that may illustrate effects of handling stress, e.g., do you recapture fish in proportion to what you expect, or does there appear to be differential survival.
- Monitor the impact of annual harvest on population abundance and population size structure.
- Identify and assess the effects of recreational and commercial fishing activities on post-release survival of lower Columbia River white sturgeon.
- Determine the economic value of white sturgeon fisheries in those lower Columbia River waters downstream of Bonneville Dam.
- Monitor white sturgeon enforcement efforts to determine if there is a change in the number of violations, as they relate to the 2009 enforcement effort level.
- Identify and assess the magnitude, extent, and effects of illegal harvest on lower Columbia River white sturgeon. Include estimates of illegal harvest when evaluating whether target exploitation rates are being met.
- Model the impacts of a variety of harvest regimes, including estimated illegal harvest and post-release mortality from commercial and recreational fishing, on lower Columbia River white sturgeon population productivity.

**11.2.2.6 Incidental Hydrosystem Mortality**

*Description* – Operations at Bonneville Dam can result in the direct mortality of lower Columbia River white sturgeon. Mortalities mainly result from offline turbine units being brought online, the dewatering of turbine draft tubes for scheduled and emergency maintenance, and dewatering fishways at Bonneville Dam for maintenance.

*Management Strategy* – Minimize incidental white sturgeon mortality associated with FCRPS operations.

*Recommended Management Actions*

- Work with the USACE to develop and implement procedures designed to block access to turbine draft tubes during turbine dewatering and other maintenance operations as necessary to minimize and avoid white sturgeon entrainment. Conduct salvage

operations for any white sturgeon entrained after emergency turbine dewatering procedures.

- Work with the USACE to develop and implement procedures to minimize mortality related to the bringing turbines online.
- Work with the USACE to develop and implement procedures to enumerate and document operational white sturgeon mortalities.

#### *Action Effectiveness Standards*

- Procedures are adopted to minimize white sturgeon operation losses and to enumerate and document those losses that do occur.
- Operational losses related to turbine dewatering and the bringing of turbines online are reduced each year in the future to levels that are initially less than current (2009) documented levels, and eventually stabilized at the lowest achievable level.
- Losses of white sturgeon that occur due to maintenance and operation at Bonneville Dam are mitigated.

#### *Recommended Research, Monitoring, and Evaluation*

- Monitor operations and procedures at Bonneville dam to assure recommendations have been implemented to reduce white sturgeon mortality events. Evaluate the success of implemented procedures, and maintain a database of operational mortalities.
- Identify, assess, and minimize downstream passage mortality at Bonneville Dam.
- Model the impacts of incidental hydrosystem mortality on lower Columbia River white sturgeon population dynamics.

### **11.2.2.7 In-water Work Activity**

*Description* – A variety of in-water work activities, including channel maintenance, gravel extraction, pile-row removal, and commercial and non-commercial navigation occur in the lower Columbia River, and may affect white sturgeon populations within this reach.

*Management Strategy* – Protect lower Columbia River white sturgeon populations and white sturgeon habitat from impacts associated with in-water work activity; mitigate unavoidable negative impacts.

#### *Recommended Management Actions*

- Recommend modifications to dredging operations and other in-water work in coordination with appropriate state and federal agencies, intended to minimize operation related mortality on white sturgeon in those lower Columbia River waters downstream of Bonneville Dam.
- 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).

#### *Action Effectiveness Standards*

- Dredging and in-water work operations are conducted in consultation and cooperation with appropriate regulatory and management agencies to ensure that white sturgeon losses are minimized.
- Time and area restrictions on dredging and in-water work operations are followed.

- White sturgeon losses associated with these activities are being enumerated, reported and mitigated.

*Recommended Research, Monitoring, and Evaluation*

- Monitor dredging and in-water work to document operational related white sturgeon mortality.
- Assess the effects of dredging and dredge spoil deposition on lower Columbia River aquatic invertebrate communities.
- Identify and assess the effects of commercial navigation and recreational boat use on white sturgeon in the lower Columbia River.
- Identify and assess the effects of gravel extraction, construction, and remediation related dredging activities on lower Columbia River white sturgeon.
- Identify and assess the impacts of in-water construction on white sturgeon in the lower Columbia River.
- Investigate the role of pile rows and similar structures in the proposed lower Columbia River white sturgeon ecology.

### **11.3 Recommended Research, Monitoring, and Evaluation Needed to Address Identified Critical Unknowns and Data Gaps**

*Recommended Research, Monitoring and Evaluation* are those activities needed by regional managers and scientists to address critical uncertainties or fill in data gaps. The results of any implemented research, monitoring and evaluation programs should be used to determine if the uncertainty or data gap that was addressed should now be considered a critical constraint, limiting factor, or threat. For any new constraints, limiting factors, or threats, Recommended Management Strategies, Actions and Action Effectiveness Standards will then be developed. The results of any implemented research, monitoring and evaluation regimes should also be documented annually with a formalized reporting process.

#### **11.3.1 Uncertainty in Abundance Estimates**

*Description* – A large degree of uncertainty surrounds the abundance of white sturgeon in the lower Columbia River populations segment.

*Recommended Research, Monitoring, and Evaluation*

- Identify and evaluate traditional and novel capture and/or non-capture population abundance estimate designs for juvenile, sub-adult, and adult white sturgeon in the lower Columbia River population segment, including those waters outside of the mainstem Columbia River.
- Estimate population abundance for age-0, juvenile, sub-adult, and adult white sturgeon downstream of Bonneville Dam using appropriate techniques and minimize biases associated with sampling regimes and analytical processes.
- Investigate the feasibility and use of benthic trawls or epibenthic sleds for collecting white sturgeon in size ranges difficult to collect with other gears.
- Evaluate utility of annual effective female population size estimates using nuclear DNA.
- Correlate age-0 indexing information with estimated juvenile abundances and back calculated egg-to-age-1 survival rates.

### **11.3.2 Optimal Adult Abundance Level**

*Description* – The optimal abundance level for lower Columbia River adult white sturgeon is currently unknown.

*Recommended Research, Monitoring, and Evaluation*

- Investigate the feasibility of developing a lower Columbia River white sturgeon stock-recruitment relationship or other production metric that is capable of relating the size of the adult population to recruitment of the number of age-1 juveniles, or to recruitment of the number of sub-adults and adults that comprise the age/size range of the recreationally and commercially harvestable portion of the population.
- Monitor adult female population size and annual recruitment to sub-adult life stage.

### **11.3.3 Distribution and Habitat Usage**

*Description* – 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.

*Recommended Research, Monitoring, and Evaluation*

- Monitor white sturgeon distribution throughout those lower Columbia River waters downstream of Bonneville Dam to assess temporal and spatial habitat usage using fisheries and fisheries-independent monitoring techniques.
- Instrument white sturgeon with acoustic and/or radio transmitters to work in coordination with the Pacific Ocean Shelf Tracking (POST) program and other telemetry receivers to determine marine, estuarine, and freshwater habitat usage; work cooperatively with green sturgeon researchers to maximize receiver systems in coastal waterways.
- Investigate the utility of fin spine microchemistry to analyze interchange of white sturgeon between lower Columbia River and coastal waterways.
- Determine the use of bed forms and substrates by white sturgeon in those lower Columbia River waters downstream of Bonneville Dam to better understand micro and diel habitat usage.
- Produce maps and digital datasets that spatially and temporally describe and identify white sturgeon use of the lower Columbia and Willamette rivers.
- Conduct, genetic and recruitment investigations of white sturgeon residing in the Willamette River upstream of Willamette Falls to determine if population is a) distinct, and/or b) successfully recruiting individuals to the population through natural production.

### **11.3.4 Stock Composition of Coastal and Marine Population Components**

*Description* – The stock composition of white sturgeon inhabiting those lower Columbia River waters downstream of Bonneville Dam is unknown.

*Recommended Research, Monitoring, and Evaluation*

- Investigate the utility of genetic analysis tools for estimating the proportions of Columbia, Sacramento, and Fraser River stocks composing the white sturgeon population within those lower Columbia River waters downstream of Bonneville Dam. If these tools prove useful, analyze the stock composition of white sturgeon that occur within these areas.

- Monitor white sturgeon populations throughout those lower Columbia River habitats downstream of Bonneville Dam, including the Willamette River and evaluate the extent and distribution of the population using fisheries and fisheries-independent monitoring techniques.

### **11.3.5 Impacts of Global Climate Change**

*Description* – Global climate change is likely to have a variety of effects on the lower Columbia River and the white sturgeon populations within.

*Recommended Research, Monitoring, and Evaluation*

- Monitor white sturgeon condition and spawn timing as a possible response to, and as a potential bellwether for, systemic changes in the lower Columbia River due to global climate change.
- Model the effects of water temperature increases, changes in the seasonality of the freshet and low elevation run-off, and possible changes in salt-wedge intrusion on white sturgeon spawning success and population dynamics within those lower Columbia River waters downstream of Bonneville Dam.
- Monitor and model the effects the above mentioned climate changes on white sturgeon food resources within the lower Columbia River white sturgeon population segment, including the Columbia River mainstem, estuarine, and marine waters.

### **11.3.6 Population Viability**

*Description* – Although the probability that the lower Columbia River white sturgeon population will persist in perpetuity has recently been forecast, the model used to forecast it has not been through the peer reviewed process.

*Recommended Research, Monitoring, and Evaluation*

- Fully vet through a peer reviewed process the recently developed population dynamics based ODFW PVA model that will be used for assessing current status in relation to the desired and conservation status benchmarks.
- Evaluate the utility of modifying the individual based model approach used in the Snake River white sturgeon PVA model (Jager et al. 2000) as an alternative persistence modeling approach.

### **11.3.7 Available native forage species**

*Description* – Declines from historic levels in white sturgeon native forage species (e.g., Pacific salmon species, Pacific lampreys, and eulachon) have been documented in the lower Columbia River and tributaries. Additionally, the status and abundance levels of native invertebrate populations, such as amphipods and mollusks, which were historically important food resources for white sturgeon, are unknown.

*Recommended Research, Monitoring, and Evaluation*

- Monitor lamprey and salmon returns to the Columbia River through passage counts at Bonneville Dam and Willamette Falls, and eulachon returns through a combination of scientific test sampling of adults, and early life history (larval and egg) investigations; support actions aimed at rebuilding those populations towards desired and historic levels.

- Investigate white sturgeon feeding ecology to determine the current relative importance of native prey items to white sturgeon in the lower Columbia River.
- Conduct bioenergetics modeling/food web analysis to determine: a) the effects on white sturgeon of a diet consisting of various combinations of native and non-native prey items, and b) how a changing forage base through time might affect the white sturgeon population segment.
- Conduct bioenergetics modeling to determine effects on white sturgeon of operation of the FCRPS and historic loss of habitat caused by development and channel improvements for navigation.
- Conduct an assessment of native invertebrates in the lower Columbia River.
- If declines in native forage species are negatively impacting lower Columbia River white sturgeon, determine population limiting factors for Pacific lampreys, eulachon, and native invertebrates.

### **11.3.8 Introductions of Non-Native Species**

*Description* – Numerous intentional and unintentional species introductions have occurred in the lower Columbia River Basin, potentially affecting white sturgeon in a variety of ways

*Recommended Research, Monitoring, and Evaluation*

- Investigate feeding ecology to determine the relative importance of non-native prey items such as American shad and Asian clams to white sturgeon in the lower Columbia River.
- Conduct bioenergetics modeling to determine the effects on white sturgeon of a diet consisting of various combinations of native and non-native prey items (see Section 11.2.7).
- Determine if foraging on thiaminase-rich American shad has a negative effect on white sturgeon.
- Investigate inter-specific competition between: juvenile American shad and juvenile white sturgeon; Asian clams and native freshwater mussels; and Mysid shrimp and native amphipods.

### **11.3.9 Total Mortality**

*Description* – Total mortality of sub-adult and adult life-stages of white sturgeon is composed of human sources of mortality and non-human sources of mortality, and in its entirety is not currently known.

*Recommended Research, Monitoring, and Evaluation*

- Assess the current total mortality level for lower Columbia River white sturgeon.
- Identify and assess subcomponents (as addressed in Sections 10.9.1 through 10.9.8) associated with total white sturgeon mortality within the lower Columbia River.
- Investigate the utility of PIT tags and tagging and novel tag detection technologies for generating survival estimates based on year to year recaptures of white sturgeon.
- Assess *river-wide* white sturgeon losses to pinniped predation.
- Identify the periodicity and assess magnitude of stress induced reproduction failures related to both catch-and-release fisheries and failed pinniped predation events.

# **Section 12 Conservation Plan Implementation and Adaptive Management Process**

The successful implementation of this Conservation Plan's management strategies, actions, action effectiveness standards, research, monitoring, and evaluation will require a significant funding commitment and close coordination between state and federal natural resource agencies, local and tribal governing bodies, and other interested parties. What follows is a brief timeline for implementing the recommended monitoring and evaluation measures needed to assess white sturgeon population status; recommended management strategies, actions, research, monitoring, and evaluation targeting constraints, limiting factors, and threats; and recommended research, monitoring and evaluation needed to address critical uncertainties. Following these timetables is a description of the adaptive management framework and process, and triggers for conservation plan modification.

## ***12.1 Implementation Schedule***

The actions and measures recommended in Section 11 of this Conservation Plan will be phased in over time to facilitate the achievement of the desired lower Columbia River white sturgeon population status. The suggested time frame, determined through a ranking exercise conducted by technical and stakeholder advisors, for implementing the recommended management, monitoring and evaluation measures needed to assess lower Columbia River white sturgeon population status are either ongoing, immediate, or one to five years (Table 17). The suggested time frame for implementing recommended management actions, research, monitoring, and evaluation measures aimed at targeting critical constraints, limiting factors, and threats range from ongoing to 10 to 15 years (Table 18). The suggested time frame for implementing recommended research monitoring, and evaluation measures needed to address critical uncertainties and data gaps range from immediate to 10 to 15 years (Table 19).

**Table 17.** Implementation matrix for recommended monitoring and evaluation measures needed to assess the white sturgeon population in relation to desired and conservation status thresholds. Those measures identified within the implementation timeframe as “Ongoing” or “Immediate” are considered to be of the highest priority.

Biological Attribute	Recommended Monitoring and Evaluation Measures	Implementation Timeframe
	<ul style="list-style-type: none"> <li>Develop, in consultation with survey sampling statisticians, a comprehensive and detailed research, monitoring, and evaluation plan for lower Columbia River and Oregon Coast white sturgeon.</li> </ul>	<ul style="list-style-type: none"> <li>Immediate</li> </ul>
<ul style="list-style-type: none"> <li><b>Abundance</b></li> </ul>	<ul style="list-style-type: none"> <li>Conduct white sturgeon stock assessments, using non-size selective gear (e.g., set-lines), in the lower Columbia River annually to monitor size distribution, growth, condition and abundance within this reach; continue use of current population indexing tools, e.g., catch rate information.</li> <li>Conduct periodic white sturgeon stock assessments (every 5 to 10 years) in areas within those lower Columbia River waters downstream of Bonneville Dam, such as Tillamook (OR) and Willapa (WA) bays, where white sturgeon are known to congregate, using a combination of size selective and non-size selective gear.</li> <li>Conduct recreational and commercial fisheries monitoring activities for weight of evidence materials used to evaluate current status as well as trends over time of the lower Columbia River white sturgeon population segment. Information collected should include, but not necessarily be limited to: effort, number of fish of a given size caught and released, average size of catch, and tag recoveries.</li> </ul>	<ul style="list-style-type: none"> <li>Ongoing</li> <li>1 – 5 years</li> <li>Ongoing</li> </ul>
<ul style="list-style-type: none"> <li><b>Distribution</b></li> </ul>	<ul style="list-style-type: none"> <li>Monitor white sturgeon populations throughout those lower Columbia River habitats downstream of Bonneville Dam, including the Willamette River and evaluate the extent and distribution of the population using fisheries and fisheries-independent monitoring techniques.</li> </ul>	<ul style="list-style-type: none"> <li>1 – 5 years</li> </ul>
<ul style="list-style-type: none"> <li><b>Diversity</b></li> </ul>	<ul style="list-style-type: none"> <li>Monitor the genetic diversity in the lower Columbia River white sturgeon population to evaluate any changes in population parameters caused by either population expansion or increased mortality due to impoundment and other anthropogenic disturbances. Because of the longevity of white sturgeon, genetic diversity monitoring programs may be conducted on a decadal basis unless a drastic change in the lower Columbia River white sturgeon population size is suspected. Random sampling of 100 to 150 lower Columbia River white sturgeon (irrespective of age class) would provide the most accurate representation of extant genetic diversity at any particular time.</li> <li>Evaluate potential spatial stock structures by taking samples and examining diversity throughout those lower Columbia River white sturgeon populations residing downstream of Bonneville Dam.</li> <li>Further develop the ability to estimate spawner contributions to wild populations by improving analysis techniques, and improve fish relatedness determination methods to the point</li> </ul>	<ul style="list-style-type: none"> <li>1 – 5 years</li> <li>1 – 5 years</li> <li>1 – 5 years</li> </ul>

	where unrelated, half-sibling, and full-sibling individuals can be easily and accurately identified.	
<ul style="list-style-type: none"> <li><b>Productivity</b></li> </ul>	<ul style="list-style-type: none"> <li>Index annual levels of, and variation in, white sturgeon recruitment in the free-flowing Columbia River downstream of Bonneville Dam. Correlate age-0 indexing data to juvenile abundance estimates and to estimated egg-to-age-1 survival rates.</li> <li>Evaluate use of early life history sampling (e.g., egg mats and larval tows) to index white sturgeon productivity in the lower Columbia and Willamette Rivers and potentially compare productivity of each.</li> <li>Using genetic tools estimate spawner contributions to juvenile white sturgeon multi-year cohorts.</li> <li>Monitor spawning and rearing conditions and available habitat via water releases at Bonneville Dam and spawning periodicity through mark and recapture maturity work; ensure spawning success and recruitment to age 1 by optimizing water releases and through continued time and area management of sport and commercial fisheries in the Columbia River.</li> <li>Conduct white sturgeon stock assessments, of sufficient mark group magnitude and geographic scope, in the lower Columbia River annually to monitor size distribution, growth, condition and abundance within this reach; continue use of current population indexing tools, e.g., catch rate information.</li> <li>Conduct periodic white sturgeon stock assessments, of sufficient effort and geographic scope, (every 5 years) in areas outside the lower Columbia River, such as Tillamook (OR) and Willapa (WA) bays, where white sturgeon are known to congregate.</li> <li>Determine the relative contribution of Willamette River spawning white sturgeon to population productivity and abundance.</li> </ul>	<ul style="list-style-type: none"> <li>Ongoing</li> <li>1 – 5 years</li> <li>1 – 5 years</li> <li>1 – 5 years</li> <li>Ongoing</li> <li>1 – 5 years</li> <li>1 – 5 years</li> </ul>
<ul style="list-style-type: none"> <li><b>Habitat</b></li> </ul>	<ul style="list-style-type: none"> <li>Identify, characterize, catalogue, and monitor spatial and seasonal white sturgeon spawning and rearing habitats throughout those lower Columbia River waters downstream of Bonneville Dam, including those waters outside the Columbia River mainstem (e.g., Willamette River upstream of Willamette Falls, coastal estuaries, etc.).</li> </ul>	<ul style="list-style-type: none"> <li>1 – 5 years</li> </ul>
<ul style="list-style-type: none"> <li><b>Persistence</b></li> </ul>	<ul style="list-style-type: none"> <li>Conduct white sturgeon stock assessments in the lower Columbia River annually to monitor size distribution, growth, condition and abundance within this reach; continue use of current population indexing tools, e.g., catch rate information.</li> <li>Conduct periodic white sturgeon stock assessments (every 5 years) in areas within those lower Columbia River waters downstream of Bonneville Dam, such as Tillamook (OR) and Willapa (WA) bays, where white sturgeon are known to congregate.</li> <li>Qualitatively evaluate persistence by monitoring the status of the five other primary biological attributes.</li> <li>Fully vet through a peer reviewed process the recently ODFW developed population dynamics based PVA model that will be used for assessing current status in relation to the desired and conservation status benchmarks.</li> <li>Evaluate the utility of modifying the individual based model</li> </ul>	<ul style="list-style-type: none"> <li>Ongoing</li> <li>1 – 5 years</li> <li>1 – 5 years</li> <li>Immediate</li> <li>1 – 5 years</li> </ul>

	<p>approach used in the Snake River white sturgeon PVA model (Jager et al. 2000) as an alternative persistence modeling approach.</p>	
<ul style="list-style-type: none"> <li>• <b>Growth and Condition</b></li> </ul>	<ul style="list-style-type: none"> <li>• Conduct white sturgeon stock assessments in the lower Columbia River annually to monitor size distribution, growth, condition and abundance within this reach; continue use of current population indexing tools, e.g., catch rate information.</li> <li>• Evaluate correlations between growth and condition and environmental variables using multivariate analyses.</li> </ul>	<ul style="list-style-type: none"> <li>• Ongoing</li> <li>• 1 – 5 years</li> </ul>
<ul style="list-style-type: none"> <li>• <b>Natural Mortality and Survival</b></li> </ul>	<ul style="list-style-type: none"> <li>• Conduct white sturgeon stock assessments in the lower Columbia River annually to monitor size distribution, growth, condition and abundance within this reach; continue use of current population indexing tools, e.g., catch rate information.</li> <li>• Assess the current natural mortality and survival levels and evaluate the total mortality level for lower Columbia River white sturgeon.</li> </ul>	<ul style="list-style-type: none"> <li>• Ongoing</li> <li>• 1 – 5 years</li> </ul>
<ul style="list-style-type: none"> <li>• <b>Fishing Mortality and Harvest</b></li> </ul>	<ul style="list-style-type: none"> <li>• Conduct recreational and commercial fisheries monitoring activities for weight of evidence materials used to evaluate current status as well as trends over time of the lower Columbia River white sturgeon population segment. Information collected should include, but not necessarily be limited to, effort, number of fish of a given size caught and released, average size of catch, and tag recoveries.</li> <li>• Conduct white sturgeon stock assessments in the lower Columbia River annually to monitor size distribution, growth, condition and abundance within this reach; continue use of current population indexing tools, e.g., catch rate information.</li> <li>• Assess the current fishing mortality levels and evaluate the total mortality level for lower Columbia River white sturgeon.</li> </ul>	<ul style="list-style-type: none"> <li>• Ongoing</li> <li>• 1 – 5 years</li> <li>• 1 – 5 years</li> </ul>

Table 18. Implementation matrix for recommended management actions, research, monitoring, and evaluation measures targeting critical constraints, limiting factors, and threats. Those actions or measures identified within the implementation timeframe as “Ongoing” or “Immediate” are considered to be of the highest priority.

Strategy	Recommended Management Actions, Research, Monitoring, and Evaluation Measures	Implementation Timeframe
	<ul style="list-style-type: none"> <li>Develop and adaptive management plan for lower Columbia River and Oregon Coast white sturgeon that includes a series of explicit expectations, models and indicators to evaluate status and trends and explicit loops from monitoring results back to key trigger points.</li> </ul>	<ul style="list-style-type: none"> <li>Immediate</li> </ul>
<b>Marine Mammal Predation</b>		
<ul style="list-style-type: none"> <li>Minimize pinniped predation related mortality on lower Columbia River white sturgeon populations.</li> </ul>	<ul style="list-style-type: none"> <li>Cooperatively manage marine mammals to minimize predation of white sturgeon, especially adult white sturgeon, downstream of Bonneville Dam, including the lower Willamette River, by dispersing congregations and redistributing pinnipeds to areas outside of the current angling sanctuary, i.e., that area between Skamania Island (RM 136) and Bonneville Dam (RM 145); management may include the removal of problem animals.</li> <li>Assess <i>river-wide</i> white sturgeon losses to pinniped predation.</li> <li>Monitor marine mammal predation on white sturgeon in the vicinity of Bonneville Dam and in the remainder of those lower Columbia River waters downstream of Bonneville Dam in a temporally and spatially expanded monitoring program.</li> <li>Assess the efficacy of marine mammal hazing and recommended management efforts.</li> <li>Using the temporally and spatially expanded monitoring program, identify and assess the spatial and temporal distribution of pinnipeds in the Columbia River from the river mouth upstream to Bonneville Dam and in the Willamette River to Willamette Falls.</li> <li>Investigate feeding ecology and bioenergetics, including diel diet patterns and physiological restrictions (e.g., can they eat under water), of pinnipeds in the lower Columbia River.</li> <li>Quantify the magnitude and extent of marine mammal predation on white sturgeon populations in the entire Columbia River from the river mouth upstream to Bonneville Dam.</li> <li>Model the impact of pinniped predation and pinniped removals on lower Columbia River white sturgeon population dynamics.</li> <li>Investigate novel sea lion hazing techniques, compare effectiveness of novel techniques to currently identified and implemented techniques, and explore the feasibility of public use.</li> </ul>	<ul style="list-style-type: none"> <li>Immediate</li> <li>Immediate</li> <li>Immediate</li> <li>1 – 5 years</li> <li>1 – 5 years</li> <li>1 – 5 years</li> <li>Immediate</li> <li>1 – 5 years</li> </ul>
<b>Piscine Predation</b>		

<ul style="list-style-type: none"> <li>Minimize the impacts of piscine predation related mortality on lower Columbia River white sturgeon populations.</li> </ul>	<ul style="list-style-type: none"> <li>Operate the FCRPS to minimize predation on white sturgeon early life history stages by native and non-native predators. River flows to accomplish this would likely consist of the same flows identified in Section 11.2.2.3 for spawning. These flows would be consistent with juvenile salmonid passage and aggressive non-breach hydrosystem operations.</li> <li>Monitor piscine predation on the early life history stages of white sturgeon in the Bonneville Dam tailrace.</li> <li>Evaluate operational strategies that are designed to minimize piscine predation.</li> <li>Assess the magnitude of marine predation (e.g. seven-gill sharks) on white sturgeon.</li> <li>Investigate effects of potential predation on white sturgeon by non-native piscine predators in the lower Columbia River, e.g., American shad, walleye, and black basses <i>Micropterus spp.</i></li> </ul>	<ul style="list-style-type: none"> <li>1 – 5 years</li> <li>5 – 10 years</li> <li>5 – 10 years</li> <li>5 – 10 years</li> <li>5 – 10 years</li> </ul>
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**Habitat Quality and Quantity**

<ul style="list-style-type: none"> <li>Protect and restore high quality main channel, off channel, estuarine, and riparian white sturgeon habitat in the lower Columbia River and adjacent waters, including the Willamette River and coastal bays, estuaries and rivers.</li> </ul>	<ul style="list-style-type: none"> <li>Operate the Federal Columbia River Power System (FCRPS) to provide white sturgeon spawning and rearing habitat downstream of Bonneville Dam in sufficient quantity and quality to maintain white sturgeon population productivity. Operations should target physical conditions that maximize or optimize the quantity, quality, and distribution of spawning and/or rearing habitat as well as adjacent riparian habitat.</li> <li>Work with partners to continue restoration of floodplain and estuary rearing habitat.</li> <li>Comment on in-water work and development permits in coordination with appropriate state and federal agencies; recommend measures to ensure the negative effect of this work on white sturgeon spawning and rearing habitat in those lower Columbia River waters downstream of Bonneville Dam is minimized, avoided, or mitigated for.</li> <li>Fund additional law enforcement personnel to enforce current habitat protection laws/regulations.</li> <li>Identify, characterize, catalogue, and monitor spatial and seasonal white sturgeon spawning and rearing habitats throughout those lower Columbia River waters downstream of Bonneville Dam, including the Willamette River.</li> <li>Investigate estuarine, tidally influenced freshwater and off-channel shallow water habitat usage by juvenile and sub-adult white sturgeon.</li> <li>Evaluate the effect of the proposed construction (e.g. spill training wall) in the tailrace of Bonneville Dam on white sturgeon spawning habitat quantity, quality, and distribution.</li> <li>Determine if there is a flow-spawning relationship for white sturgeon in the Willamette River; if such a relationship exists, recommend operations of Willamette River System hydro-electric and flood control projects to ensure spawning habitat in the Willamette River.</li> <li>Identify and assess seasonal and spatial white sturgeon</li> </ul>	<ul style="list-style-type: none"> <li>Immediate</li> <li>5 – 10 years</li> <li>Immediate</li> <li>1 – 5 years</li> <li>1 – 5 years</li> <li>1 – 5 years</li> <li>1 – 5 years</li> <li>5 – 10 years</li> <li>1 – 5 years</li> </ul>
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	<p>habitat usage of nearshore (to 600 feet) marine habitats and migration corridors.</p> <ul style="list-style-type: none"> <li>• Model the impact of past spawning and rearing habitat losses on lower Columbia River white sturgeon population dynamics.</li> <li>• Develop more advanced habitat modeling tools to better quantify the amount of spawning and rearing habitat available in those lower Columbia River waters downstream of Bonneville Dam.</li> <li>• Monitor habitat enforcement efforts to determine if there is a change in the number of violations, as they relate to the 2009 enforcement effort level.</li> </ul>	<ul style="list-style-type: none"> <li>• 5 – 10 years</li> <li>• 5 – 10 years</li> <li>• 5 – 10 years</li> </ul>
<b>Habitat Fragmentation</b>		
<ul style="list-style-type: none"> <li>• Restore Columbia River connectivity to promote healthy lower Columbia River white sturgeon populations.</li> </ul>	<ul style="list-style-type: none"> <li>• Operate the FCRPS to minimize white sturgeon habitat fragmentation downstream of, and allow for white sturgeon upstream and downstream passage at Bonneville Dam. Habitat fragmentation downstream can be minimized by limiting power peaking and load following operations. Investigate potential passage options at Bonneville Dam, e.g., renovating the existing fish lift, retrofitting fish ladders, or potentially making modifications to the navigation lock.</li> <li>• Restore the connectivity between rearing habitats (main channel, side channels, oxbows, and tidewaters) in the floodplain and estuary.</li> <li>• Monitor white sturgeon passage at Bonneville Dam and Willamette Falls fish passage facilities; assess residence time in fishways.</li> <li>• Assess size-specific upstream and downstream passage and survival through non-fishway passage routes (e.g., navigation locks at Bonneville Dam and Willamette Falls, turbine passage, juvenile salmon bypass systems).</li> <li>• Identify and understand the advantages, disadvantages, and possible obligations to providing upstream and downstream white sturgeon passage at Bonneville Dam.</li> <li>• Conduct studies to understand how fragmentation of wintering and spawning habitat downstream from Bonneville Dam caused by tailrace construction (e.g., a spillway training wall) affects adult sturgeon movements and the quality and quantity of spawning habitat.</li> <li>• Identify and assess potential sources of habitat fragmentation and fragmented habitats within those lower Columbia River waters downstream of Bonneville Dam. Specific assessments should include, but not be limited to, fragmentation resulting from tides and fragmentation resulting from 1) daily hydropower operations and 2) long-term changes in fragmentation resulting from shifting the flow regime for hydropower operation.</li> <li>• Monitor white sturgeon usage of rearing habitats restored in the floodplain and estuary, and the potential for stranding in these habitats.</li> </ul>	<ul style="list-style-type: none"> <li>• 1 – 5 years</li> <li>• 5 – 10 years</li> <li>• 5 – 10 years</li> <li>• 5 – 10 years</li> <li>• 10 – 15 years</li> <li>• 1 – 5 years</li> <li>• 1 – 5 years</li> <li>• 1 – 5 years</li> </ul>
<b>Flow and Flow Variation</b>		

<ul style="list-style-type: none"> <li>• Provide and maintain consistent flows and restore historic Columbia River hydrograph, when possible, to promote healthy lower Columbia River white sturgeon populations.</li> </ul>	<ul style="list-style-type: none"> <li>• Configure and operate the Bonneville Dam power houses and spillway to maximize the amount of high quality spawning habitat downstream from the dam during the time period when peak spawning occurs (i.e. when temperatures are between 54 - 61 °F). The FCRPS Biological Opinion (NMFS 2008) requires 100 kcfs of spill, or spill to the gas cap during the spring sturgeon spawning season. Spill should be maintained at 100 kcfs as called for in the Biological Opinion, with some amount of variation around this specified level to control total dissolved gas.</li> <li>• Evaluate spawning habitat in the transition zones ([a] between Bradford and Cascade Islands, and Tanner Creek; [b] downstream from Tanner Creek) downstream from Bonneville Dam to determine how a range of operations at the dam affect hydraulics in the transition zones and the resulting suitability of spawning habitat.</li> <li>• Develop a plan to provide constant flow, i.e., flat-load, one powerhouse at a continuous discharge that produces high quality, stable sturgeon spawning habitat, while following load at the other powerhouse, after determining the suitability of the hydraulics downstream from each power house and describing how that suitability changes across a range of stream flows. There may be some flexibility to differentially load the two Bonneville Dam power houses in order to minimize variation and maximize stability of conditions downstream from one of the locations.</li> <li>• Monitor hourly spill and power house discharge levels at Bonneville Dam.</li> <li>• Conduct the necessary research to determine the flow configurations for Recommended Management Actions and Action Effectiveness Standards.</li> <li>• Identify how flow routing at Bonneville Dam affects spawning success below the spillway, power houses, and transition zones, egg deposition, dispersal of free swimming embryos, and access to rearing habitats.</li> <li>• Assess white sturgeon habitat given the three tailraces and partitioning of flows through the powerhouses and spillway downstream from Bonneville Dam.</li> <li>• Determine the effects of power peaking operations and load following at Bonneville Dam on white sturgeon spawning behavior and success.</li> <li>• Investigate riparian and off-channel shallow water habitat usage by white sturgeon early life history stages in the Ives and Pierce Island complex downstream of Bonneville Dam and determine potential effects of daily and hourly flow variations associated with power peaking on survival of these early life history stages.</li> </ul>	<ul style="list-style-type: none"> <li>• Immediate</li> <li>• 1 – 5 years</li> <li>• 1 - 5 years</li> <li>• 1 – 5 years</li> </ul>
<p><b>Water Quality</b></p>		
<ul style="list-style-type: none"> <li>• Maintain water quality in the lower Columbia River to promote healthy lower Columbia River white</li> </ul>	<ul style="list-style-type: none"> <li>• Operate FCRPS to ensure water temperatures and dissolved gas supersaturation levels are within white sturgeon spawning, incubation, and early life stage development and dispersal criteria downstream of Bonneville Dam.</li> </ul>	<ul style="list-style-type: none"> <li>• Immediate</li> </ul>

<p>sturgeon populations and ecosystems.</p>	<ul style="list-style-type: none"> <li>• Fund additional law enforcement personnel to enforce current water quality protection laws/regulations.</li> <li>• Monitor water temperatures and total dissolved gas levels in the Bonneville Dam tailrace.</li> <li>• Identify and assess the impacts of FCRPS operations on water temperatures in the lower Columbia River.</li> <li>• Identify the effects of low turbidity on white sturgeon recruitment in the lower Columbia River.</li> <li>• Identify the effects of total dissolved gasses on white sturgeon survival in the lower Columbia River.</li> <li>• Determine the spatial and temporal distribution of white sturgeon early life stages (egg through dispersal and larval settlement) downstream from Bonneville Dam.</li> <li>• Implement cause and effect studies to determine if pollutants and contaminants affect white sturgeon survival and spawning success in the lower Columbia River.</li> <li>• Model the effects of changes in a variety of water quality parameters on lower Columbia River white sturgeon population dynamics.</li> <li>• Conduct “dose-response” studies to resolve issues surrounding toxins of concern by identifying the specific toxin and contaminant effects on white sturgeon survival and spawning success.</li> <li>• Monitor water quality enforcement efforts to determine if there is a change in the number of violations, as they relate to the 2009 enforcement effort level.</li> </ul>	<ul style="list-style-type: none"> <li>• 1 – 5 years</li> <li>• 5 – 10 years</li> <li>• 1 – 5 years</li> </ul>
<p><b>Fishing Effects</b></p>		
<ul style="list-style-type: none"> <li>• Guard against over-utilization and manage lower Columbia River white sturgeon populations to provide ecological, socio-economic, and cultural benefits now and into the future.</li> </ul>	<ul style="list-style-type: none"> <li>• In consultation with the appropriate state agencies and management entities, fund intensive white sturgeon fishery management including: the identification of annual sustainable recreational and commercial harvest levels through population simulation that accounts for variable natural production, growth rate, and abundance; and conduct harvest monitoring that enables active in-season management to attain pre-determined escapement levels to the adult population.</li> <li>• Recommend implementing annual harvest levels based on an annual sustainable exploitation rate of 16% and estimated population abundances of 38 – 54 inch FL white sturgeon; continue to model population responses to implemented fisheries.</li> <li>• Continue the use of exploitation rate fishery management buffers to shield lower Columbia River white sturgeon populations from uncertainties associated with constraints, limiting factors and threats, and critical unknowns and data gaps. The white sturgeon population in the mainstem lower Columbia River is currently being managed to modeled sustainable exploitation rate of 22.5% exploitation rate on 38 – 54 inch FL. This plan is recommending a 16% exploitation rate on the same size fish to account for uncertainties associated with pinniped predation and recruitment. This management buffer is deliberate, with the goal of lowering exploitation rates from predetermined targets to reduce potential risks to</li> </ul>	<ul style="list-style-type: none"> <li>• Ongoing</li> <li>• Immediate</li> <li>• Ongoing</li> </ul>

	<p>the white sturgeon population (Fieberg 2004).</p> <ul style="list-style-type: none"> <li>• Implement educational and angler awareness programs to inform the public of the consequences of over-harvest of long-lived white sturgeon.</li> <li>• Fund additional law enforcement personnel to enforce current laws/regulations that protect lower Columbia River white sturgeon.</li> <li>• Use population simulation with updated parameter estimates for survival by size class, age at length, age at maturity, spawning frequency or proportion that contribute to spawning, in order to refine the currently accepted estimate of the OSY exploitation rate for the lower Columbia River white sturgeon population.</li> <li>• Monitor set and implemented white sturgeon recreational and commercial fisheries, including catch and release recreational fisheries.</li> <li>• Conduct mark-recapture survival analyses that may illustrate effects of handling stress, e.g., do you recapture fish in proportion to what you expect, or does there appear to be differential survival.</li> <li>• Monitor the impact of annual harvest on population abundance and population size structure.</li> <li>• Identify and assess the effects of recreational and commercial fishing activities on post-release survival of lower Columbia River white sturgeon.</li> <li>• Determine the economic value of white sturgeon fisheries in those lower Columbia River waters downstream of Bonneville Dam.</li> <li>• Monitor white sturgeon enforcement efforts to determine if there is a change in the number of violations, as they relate to the 2009 enforcement effort level.</li> <li>• Identify and assess the magnitude, extent, and effects of illegal harvest on lower Columbia River white sturgeon. Include estimates of illegal harvest when evaluating whether target exploitation rates are being met.</li> <li>• Model the impacts of a variety of harvest regimes, including estimated illegal harvest and post-release mortality from commercial and recreational fishing, on lower Columbia River white sturgeon population productivity.</li> </ul>	<ul style="list-style-type: none"> <li>• 10 – 15 years</li> <li>• 1 – 5 years</li> <li>• Immediate</li> <li>• Ongoing</li> <li>• 1 – 5 years</li> <li>• Ongoing</li> <li>• 1 – 5 years</li> <li>• 5 – 10 years</li> <li>• 1 – 5 years</li> <li>• 1 – 5 years</li> <li>• 1 – 5 years</li> </ul>
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**Incidental Hydrosystem Mortality**

<ul style="list-style-type: none"> <li>• Minimize incidental white sturgeon mortality associated with FCRPS operations.</li> </ul>	<ul style="list-style-type: none"> <li>• Work with the USACE to develop and implement procedures designed to block access to turbine draft tubes during turbine dewatering and other maintenance operations as necessary to minimize and avoid white sturgeon entrainment. Conduct salvage operations for any white sturgeon entrained after emergency turbine dewatering procedures.</li> <li>• Work with the USACE to develop and implement procedures to minimize mortality related to the bringing turbines online.</li> <li>• Work with the USACE to develop and implement procedures to enumerate and document operational white sturgeon mortalities.</li> </ul>	<ul style="list-style-type: none"> <li>• Immediate and ongoing</li> <li>• Immediate</li> <li>• Immediate</li> </ul>
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	<ul style="list-style-type: none"> <li>• Monitor operations and procedures at Bonneville dam to assure recommendations have been implemented to reduce white sturgeon mortality events. Evaluate the success of implemented procedures, and maintain a database of operational mortalities.</li> <li>• Identify, assess, and minimize downstream passage mortality at Bonneville Dam.</li> <li>• Model the impacts of incidental hydrosystem mortality on lower Columbia River white sturgeon population dynamics.</li> </ul>	<ul style="list-style-type: none"> <li>• 1 – 5 years</li> <li>• 10 – 15 years</li> <li>• 1 – 5 years</li> </ul>
<b>In-water Work Activity</b>		
<ul style="list-style-type: none"> <li>• Protect lower Columbia River white sturgeon populations and white sturgeon habitat from impacts associated with in-water work activity; mitigate unavoidable negative impacts.</li> </ul>	<ul style="list-style-type: none"> <li>• Recommend modifications to dredging operations and other in-water work in coordination with appropriate state and federal agencies, intended to minimize operation related mortality on white sturgeon in those lower Columbia River waters downstream of Bonneville Dam.</li> <li>• 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).</li> <li>• Monitor dredging and in-water work to document operational related white sturgeon mortality.</li> <li>• Assess the effects of dredging and dredge spoil deposition on lower Columbia River aquatic invertebrate communities.</li> <li>• Identify and assess the effects of commercial navigation and recreational boat use on white sturgeon in the lower Columbia River.</li> <li>• Identify and assess the effects of gravel extraction, construction, and remediation related dredging activities on lower Columbia River white sturgeon.</li> <li>• Identify and assess the impacts of in-water construction on white sturgeon in the lower Columbia River.</li> <li>• Investigate the role of pile rows and similar structures in the proposed lower Columbia River white sturgeon ecology.</li> </ul>	<ul style="list-style-type: none"> <li>• Immediate</li> <li>• Immediate</li> <li>• Immediate</li> <li>• 1 – 5 years</li> <li>• 5 – 10 years</li> <li>• 5 – 10 years</li> <li>• 1 – 5 years</li> <li>• 1 – 5 years</li> </ul>

Table 19. Implementation matrix for recommended research, monitoring, and evaluation needed to address identified critical uncertainties and data gaps. Those measures identified within the implementation timeframe as “Ongoing” or “Immediate” are considered to be of the highest priority.

Data Gap	Recommended Research, Monitoring, and Evaluation Measures	Implementation Timeframe
<ul style="list-style-type: none"> <li><b>Uncertainty in Abundance Estimates</b></li> </ul>	<ul style="list-style-type: none"> <li>Identify and evaluate traditional and novel capture and/or non-capture population abundance estimate designs for juvenile, sub-adult, and adult white sturgeon in the lower Columbia River.</li> <li>Estimate population abundance for age-0, juvenile, sub-adult, and adult white sturgeon downstream of Bonneville Dam using appropriate techniques and minimize biases associated with sampling regimes and analytical processes.</li> <li>Investigate the feasibility and use of benthic trawls or epibenthic sleds for collecting white sturgeon in size ranges difficult to collect with other gears.</li> <li>Evaluate utility of annual effective female population size estimates using nuclear DNA.</li> <li>Correlate age-0 indexing information with estimated juvenile abundances and back calculated egg-to-age-1 survival rates.</li> </ul>	<ul style="list-style-type: none"> <li>Immediate</li> <li>Immediate</li> <li>1 – 5 years</li> <li>5 – 10 years</li> <li>Immediate</li> </ul>
<ul style="list-style-type: none"> <li><b>Optimal Adult Abundance Level</b></li> </ul>	<ul style="list-style-type: none"> <li>Investigate the feasibility of developing a lower Columbia River white sturgeon stock-recruitment relationship or other production metric that is capable of relating the size of the adult population to recruitment of the number of age-1 juveniles, or to recruitment of the number of sub-adults and adults that comprise the age/size range of the recreationally and commercially harvestable portion of the population.</li> <li>Monitor adult female population size and annual recruitment to sub-adult life stage.</li> </ul>	<ul style="list-style-type: none"> <li>1 – 5 years</li> <li>1 – 5 years</li> </ul>
<ul style="list-style-type: none"> <li><b>Distribution and Habitat Usage</b></li> </ul>	<ul style="list-style-type: none"> <li>Monitor white sturgeon distribution throughout those lower Columbia River waters downstream of Bonneville Dam to assess temporal and spatial habitat usage using fisheries and fisheries-independent monitoring techniques.</li> <li>Instrument white sturgeon with acoustic and/or radio transmitters to work in coordination with the Pacific Ocean Shelf Tracking (POST) program and other telemetry receivers to determine marine, estuarine, and freshwater habitat usage; work cooperatively with green sturgeon researchers to maximize receiver systems in coastal waterways.</li> <li>Investigate the utility of fin spine microchemistry to analyze interchange of white sturgeon between lower Columbia River and coastal waterways.</li> <li>Determine the use of bed forms and substrates by white sturgeon in those lower Columbia River waters downstream of Bonneville Dam to better understand micro and diel habitat usage.</li> <li>Produce maps and digital datasets that spatially and temporally describe and identify white sturgeon use of the lower Columbia and Willamette rivers.</li> </ul>	<ul style="list-style-type: none"> <li>1 – 5 years</li> <li>1 – 5 years</li> <li>1 – 5 years</li> <li>5 – 10 years</li> <li>1 – 5 years</li> </ul>

	<ul style="list-style-type: none"> <li>• Conduct, genetic and recruitment investigations of white sturgeon residing in the Willamette River upstream of Willamette Falls to determine if population is a) distinct, and/or b) successfully recruiting individuals to the population through natural production.</li> </ul>	<ul style="list-style-type: none"> <li>• 1 – 5 years</li> </ul>
<ul style="list-style-type: none"> <li>• <b>Stock Composition of Coastal and Marine Population Components</b></li> </ul>	<ul style="list-style-type: none"> <li>• Investigate the utility of genetic analysis tools for estimating the proportions of Columbia, Sacramento, and Fraser River stocks composing the white sturgeon population within those lower Columbia River waters downstream of Bonneville Dam. If these tools prove useful, analyze the stock composition of white sturgeon that occur within these areas.</li> <li>• Monitor white sturgeon populations throughout those lower Columbia River habitats downstream of Bonneville Dam, including the Willamette River and evaluate the extent and distribution of the population using fisheries and fisheries-independent monitoring techniques.</li> </ul>	<ul style="list-style-type: none"> <li>• 1 – 5 years</li> <li>• Ongoing</li> </ul>
<ul style="list-style-type: none"> <li>• <b>Impacts of Global Climate Change</b></li> </ul>	<ul style="list-style-type: none"> <li>• Monitor white sturgeon condition and spawn timing as a possible response to, and as a potential bellwether for, systemic changes in the lower Columbia River due to global climate change.</li> <li>• Model the effects of water temperature increases, changes in the seasonality of the freshet and low elevation run-off, and possible changes in salt-wedge intrusion on white sturgeon spawning success and population dynamics within those lower Columbia River waters downstream of Bonneville Dam.</li> <li>• Monitor and model the effects the above mentioned climate changes on white sturgeon food resources within the lower Columbia River white sturgeon population segment, including the Columbia River mainstem, estuarine, and marine waters.</li> </ul>	<ul style="list-style-type: none"> <li>• 10 – 15 years</li> <li>• 10 – 15 years</li> <li>• 5 – 10 years</li> </ul>
<ul style="list-style-type: none"> <li>• <b>Population Viability</b></li> </ul>	<ul style="list-style-type: none"> <li>• Fully vet through a peer reviewed process the recently ODFW developed population dynamics based PVA model that will be used for assessing current status in relation to the desired and conservation status benchmarks.</li> <li>• Evaluate the utility of modifying the individual based model approach used in the Snake River white sturgeon PVA model (Jager et al. 2000) as an alternative persistence modeling approach.</li> </ul>	<ul style="list-style-type: none"> <li>• Immediate</li> <li>• 1 – 5 years</li> </ul>
<ul style="list-style-type: none"> <li>• <b>Available Native Forage Species</b></li> </ul>	<ul style="list-style-type: none"> <li>• Monitor lamprey, eulachon, and salmon returns to the Columbia River, support actions aimed at building those populations towards historic levels.</li> <li>• Investigate white sturgeon feeding ecology to determine the current relative importance of native prey items to white sturgeon in the lower Columbia River.</li> <li>• Conduct bioenergetics modeling/food web analysis to determine: a) the effects on white sturgeon of a diet consisting of various combinations of native and non-native prey items, and b) how a changing forage base through time might affect the white sturgeon population segment.</li> <li>• Conduct bioenergetics modeling to determine effects on white sturgeon of operation of the FCRPS and historic loss of habitat caused by development and channel improvements for navigation.</li> </ul>	<ul style="list-style-type: none"> <li>• 1 – 5 years</li> </ul>

	<ul style="list-style-type: none"> <li>• Conduct an assessment of native invertebrates in the lower Columbia River.</li> <li>• If declines in native forage species are negatively impacting lower Columbia River white sturgeon, determine population limiting factors for Pacific lampreys, eulachon, and native invertebrates.</li> </ul>	<ul style="list-style-type: none"> <li>• 1 – 5 years</li> <li>• 5 – 10 years</li> </ul>
<ul style="list-style-type: none"> <li>• <b>Introductions of Non-Native Species</b></li> </ul>	<ul style="list-style-type: none"> <li>• Investigate feeding ecology to determine the relative importance of non-native prey items such as American shad and Asian clams to white sturgeon in the lower Columbia River.</li> <li>• Conduct bioenergetics modeling to determine the effects on white sturgeon of a diet consisting of various combinations of native and non-native prey items (see Section 11.2.7).</li> <li>• Determine if foraging on thiaminase-rich American shad has a negative effect on white sturgeon.</li> <li>• Investigate inter-specific competition between: juvenile American shad and juvenile white sturgeon; Asian clams and native freshwater mussels; and Mysid shrimp and native amphipods.</li> </ul>	<ul style="list-style-type: none"> <li>• 1 – 5 years</li> <li>• 1 – 5 years</li> <li>• 1 – 5 years</li> <li>• 5 – 10 years</li> </ul>
<ul style="list-style-type: none"> <li>• <b>Total Mortality</b></li> </ul>	<ul style="list-style-type: none"> <li>• Assess the current total mortality level for lower Columbia River white sturgeon.</li> <li>• Identify and assess subcomponents (as addressed in sections 10.9.1 through 10.9.8) associated with total white sturgeon mortality within the lower Columbia River.</li> <li>• Investigate the utility of PIT tags and tagging and novel tag detection technologies for generating survival estimates based on year to year recaptures of white sturgeon.</li> <li>• Assess <i>river-wide</i> white sturgeon losses to pinniped predation.</li> <li>• Identify the periodicity and assess magnitude of stress induced reproduction failures.</li> </ul>	<ul style="list-style-type: none"> <li>• 1 – 5 years</li> <li>• 1 – 5 years</li> <li>• 1 – 5 years</li> <li>• Immediate</li> <li>• 1 – 5 years</li> </ul>

## 12.2 Adaptive Management Framework

This plan will follow the tenets of adaptive management, i.e., the process of modifying or changing actions and decisions based on the most up to date information available. The constraints, limiting factors, threats, critical uncertainties and data gaps as well as the actions and measures targeted at addressing them have been based on the best science currently available; however, the white sturgeon life cycle is extremely long and complex. Because of this, there remains a degree of uncertainty regarding the effectiveness of the management actions and the research, monitoring, and evaluation measures recommended in this Conservation Plan. It is because of this uncertainty that the development of a separate and complimentary adaptive management plan is essential as well as the description of a process that revisits current status when new information becomes available. This Conservation Plan will include a series of explicit expectations, models and indicators to evaluate status and trends and explicit loops from monitoring results back to key trigger points. This approach forces the careful consideration of how results will be measured and reported and how and when actions will be determined to be successful or not. As stated by Goodman et al. (2011), key adaptive management elements include the following:

- Explicit statements of problems, objectives and goals, with trigger points and possible alternatives at those points described in advance.

- Clear conceptual models of processes of concern, and simulation models supported by empirical data.
- Clear results of predictions and performance indicators from the proposed actions, along with potential alternatives if expectations are not met within explicit confidence bounds.
- A rigorous monitoring and assessment program with periodic analyses for evaluating progress and selecting alternative actions.
- A research and management team to evaluate results and, when needed, to revise goals, objectives, or actions. The team should be led by a Chief Scientist responsible and accountable for leading the program.
- An adequately funded lead agency willing to implement the recommended changes. Program duties include stimulating public discussion of scientific issues; facilitating rigorous peer review of important documents; supplying public and scientific reports; managing open retrievable databases; and revising models for continuous analysis and assessment.

### **12.2.1 Creation of Technical Management Team**

Pursuant to our adaptive management framework, a White Sturgeon Technical Management Team will be formed to monitor the lower Columbia River white sturgeon population segment within six months of Conservation Plan adoption. The White Sturgeon Technical Management Team will be made up of fisheries managers from ODFW, WDFW and federal and tribal sturgeon experts.

### **12.2.2 Schedule for Adaptive Management**

The White Sturgeon Technical Management Team will meet at least annually to review the status of lower Columbia River white sturgeon, especially as it pertains to desired and conservation status. In addition to reviewing the current status the White Sturgeon Technical Management Team will monitor progress toward addressing the constraints, limiting factors, threats, critical uncertainties, and data gaps. The results of these annual status reviews will be published on the ODFW web-site as management reports. The White Sturgeon Technical Management Team also commits to producing a more in-depth review of lower Columbia River white sturgeon status via an ODFW informational report at five year intervals. Any reports generated or data collected will be made available to the public.

### **12.2.3 Triggers for Plan Modification**

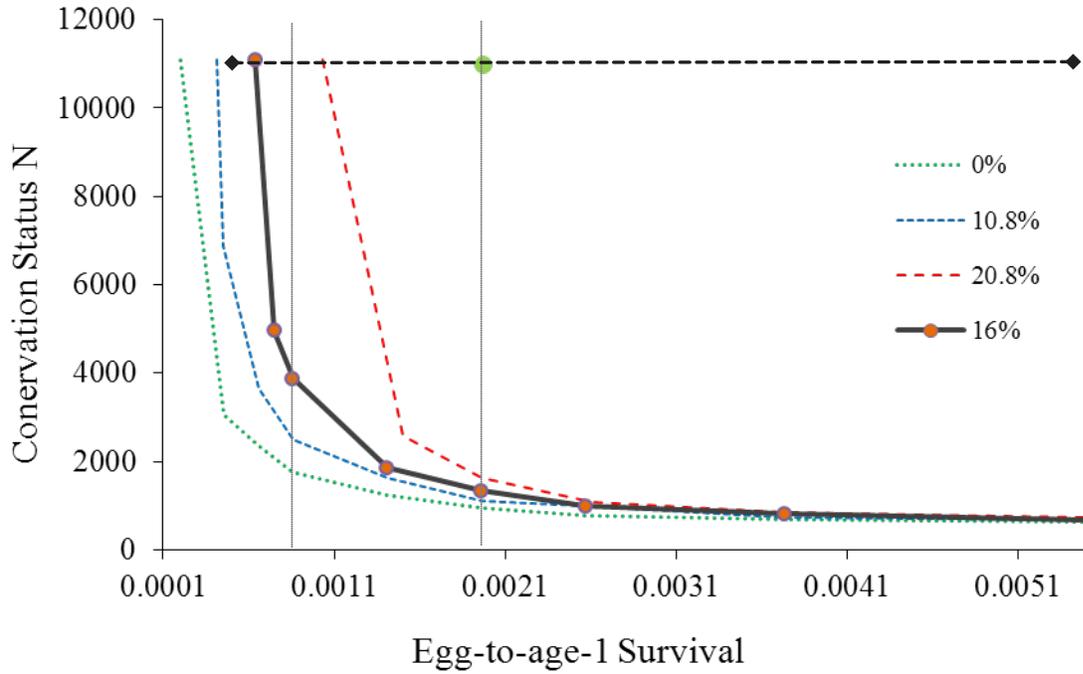
Measureable metrics are needed and have been developed to assess population status with regards to certain primary and secondary biological attributes. If any of these lower Columbia River white sturgeon population metrics were to fall below conservation thresholds, the White Sturgeon Technical Management Team will meet to determine temporary modifications to management strategies or actions that are recommended in this Conservation Plan. The type and severity of these temporary modifications should depend on which conservation criteria were realized, the current overall status of the population segment, and the projected status of the lower Columbia River white sturgeon population segment during subsequent years. Should temporary modifications not rectify, within a reasonable time frame, the conservation status of these biological attributes, a comprehensive review of the Conservation Plan and lower Columbia River white sturgeon population segment status will be undertaken as soon as feasible by the White Sturgeon Technical Management Team. Under that review, the White Sturgeon Technical Management Team may recommend permanent changes to management actions to

stop and reverse declines or other adverse effects. The Conservation Plan may be modified to provide guidance in the re-direction of population trajectories toward the desired status level.

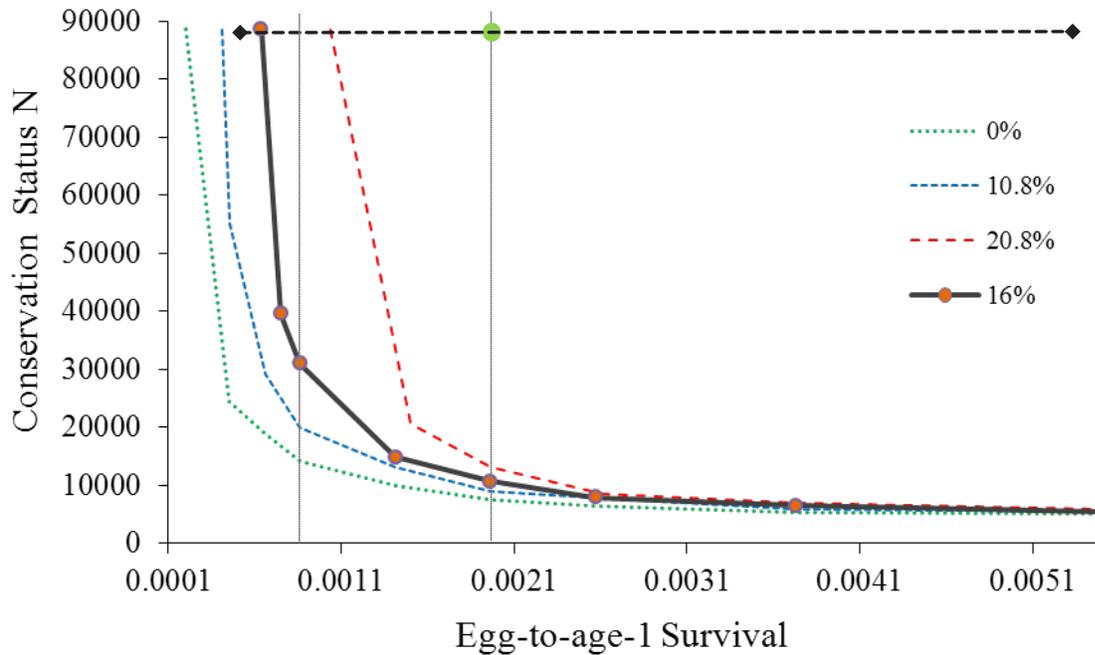
It should be noted that, due to their slow growth and multi-decadal generational turn-around, effects of management actions may not be immediately apparent. In fact it may be 5 or more years before those affects are detectable using standard stock assessing techniques and more than 10 years before those affects are detectable in fisheries.

Although none of the biological attributes discussed within the plan are trivial, abundance and productivity are the biggest drivers/predictors of viability and are considered to be of primary importance. In addition to temporary modifications, if the status of either the abundance or productivity metrics fall below the conservation status thresholds, a similar and immediate Conservation Plan and status review by the White Sturgeon Technical Management Team will take place resulting in potential plan modifications and permanent management action and strategy recommendations. Again, the type and severity of these revised recommendations and modifications will depend on where abundance and productivity metrics are in relation to each other, the current overall status of the population segment, and the projected status of the lower Columbia River white sturgeon population segment during subsequent years.

Although fisheries managers will be concerned if either the abundance or productivity metric falls below the respective conservation status threshold, the primary risk to the population is represented by both metrics falling concurrently below the conservation status thresholds. Our current estimate of white sturgeon adult abundance is approximately 11,000 fish. This combined with our current modeled estimate of egg-to-age-1 survival indicates that, when considering adults, the population is substantially above this area of concern (Figure 17), and remains so, even when considering the full range of observed egg-to-age-1 survival rates. The situation is similar for sub-adults (Figure 18) which, with the current abundance estimate of approximately 89,000 fish, also falls well above the area of concern.



**Figure 17.** Conservation curves for adult abundance and productivity estimates at 0%, 10.8%, 16%, and 20.8% exploitation rates. The green point is our current estimate of abundance and egg-to-age-1 survival. The vertical grey dotted lines indicate the median of our current estimated range of egg-to-age-1 survivals (intersects green current status point) and the median of our estimated low observed ranges of egg-to-age-1 survival rates. The horizontal grey dashed line is indicates the full range of egg-to-age-1 survival values we have observed and included in the model.



**Figure 18.** Conservation curves for sub-adult abundance and productivity estimates at 0%, 10.8%, 16%, and 20.8% exploitation rates. The green point is our current estimate of abundance and egg-to-age-1 survival. The vertical grey dotted lines indicate the median of our current estimated range of egg-to-age-1 survivals (intersects green current status point) and the median of our estimated low observed ranges of egg-to-age-1 survival rates. The horizontal grey dashed line indicates the full range of egg-to-age-1 survival values we have observed and included in the model.

#### 12.2.4 Performance Measure Checkpoints

White sturgeon generations are on the order of 25+ years, and population responses may be on a timeframe not easily grasped. For example achieving desired abundance status may take up to 20 sturgeon generations, or 500 years. Within the concept of desired status, the goal would have been met; however, 500 years is clearly beyond the scope of a human life time and hence, more short-term and immediate checkpoints are needed to assess progress toward desired or conservation status. Because of the importance of sub-adult and adult abundance to population viability and the timeframes associated with white sturgeon life history, a series of performance measures has been developed for these abundance metrics. Ideally, these measures would document, at regular time intervals, the lower Columbia River white sturgeon population segment's inexorable march toward desired status. The measures could also indicate that the population, while healthy, is not fully realizing its potential, i.e., the population is not at, or trending toward conservation status level, but neither is it on track to reach desired status during the appropriate time frame. Worse yet, the interim performance measures could indicate that the population is trending below a healthy level, or even toward conservation status.

As stated in Section 6, to define desired status by using the PVA model, a sustainable exploitation rate was determined with assumptions of maximum (worst case) projected pinniped predation rate and the lowest observed estimates of egg-to-age-1 survival. We then reset

predation and survival rates to our best estimates and modeled population response at this lower exploitation rate and current vital rate estimates. This exercise gives us quantitative measures to examine population trajectories. We determined checkpoints and modeled abundance levels at 3 years – the length of the current fisheries accord, 15 years – the average length of time it takes for male white sturgeon to reach sexual maturity, 25 years – the average length of time it takes for female white sturgeon to reach maturity, 50 years – two sturgeon generations, as well as the total 500 year (20 generations) time horizon (Table 20).

**Table 20.** Summary of status checkpoints for adult and sub-adult abundance metrics.

Checkpoint	Adults		Sub-Adults	
	Desired	Healthy	Desired	Healthy
2011 -- current	10,700	10,700	80,750	80,750
2014 -- 3 years	9,250	9,250	257,000	257,000
2026 -- 15 years	6,250	6,250	300,000	148,500
2036 -- 25 years	8,650	7,900	296,000	160,500
2061 -- 50 years	14,250	10,000	341,000	163,500
2561 -- 500 years	16,250	11,800	368,000	193,500

If, during annual assessments and at pre-determined check in points, adult abundance (Figure 19) or sub-adult abundance (Figure 20) are not in the desired solid green zone, i.e., they are in the green checked, white or red status zones, the White Sturgeon Technical Management Team may recommend temporary management actions to redirect progress towards abundance checkpoints and eventual attainment of desired status. As part of our adaptive management approach we also employ weight of evidence strategies; in this vein, harvest can serve as a proxy for abundance, and we developed similar performance measures for it (Figure 21). Should at any time, a declining trend become apparent indicating the lower Columbia River white sturgeon population is on a trajectory toward, or approaching being unhealthy, or being at conservation status, the White Sturgeon Technical Management Team may recommend management actions to immediately arrest and reverse the declining trend.

### 12.2.5 Potential Management Actions

Should checkpoints discussed above not be reached, or declining trends be witnessed, the White Sturgeon Technical Management Team may recommend management actions to help redirect population trajectories. In reality, few actions exist that may be rapidly taken to affect immediate, meaningful change in population abundance or productivity. These primary actions are: fishery management modifications, e.g., harvest restrictions, fishing sanctuaries; reducing predation related mortality, e.g., removing or redistributing pinnipeds away from areas that contain white sturgeon concentrations; and supplementation efforts, e.g., hatchery or transplanted fish released into the lower Columbia River.

Due to the marine mammal protection and endangered species acts, there are, at the time of this writing, no management actions available to fish and wildlife managers to dramatically change pinniped predation related mortality. This lack of available options severely limits current utility of “predation reductions” as a management action.

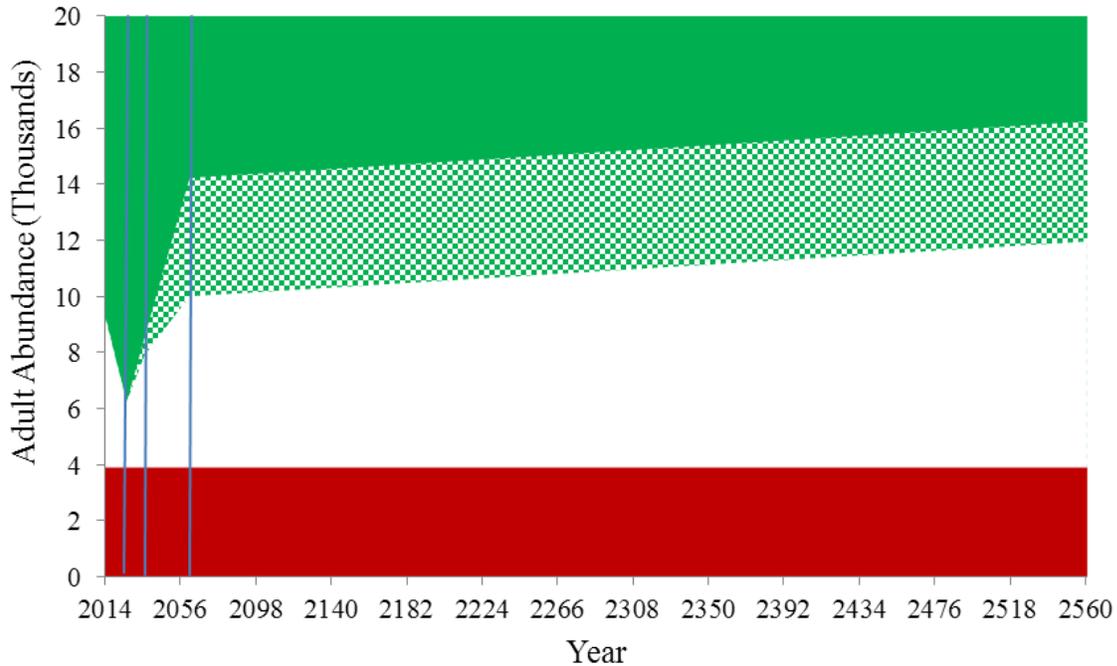


Figure 19. Performance measure scenario and checkpoints for white sturgeon adult abundance. The interface between the green and the green checked zone is the projected desired status line. That is, the modeled population number with a sustainable 16% exploitation rate and current estimates of egg-to-age-1 survival and pinniped predation rates. The interface between the green checked and white is the 16% and lowest observed survival rates. The interface between white and red is the conservation status. Values in solid green are in the desired healthy and harvestable zone, those in the green checked the healthy but not fully harvestable zone, those in white zone are not healthy and those red are in the conservation status zone. Vertical lines indicate checkpoints. The first checkpoint (3 years) is at 2014 (and is the y-axis), additional checkpoints are in 15 years (2026), 25 years (2036), and 50 years (2061).

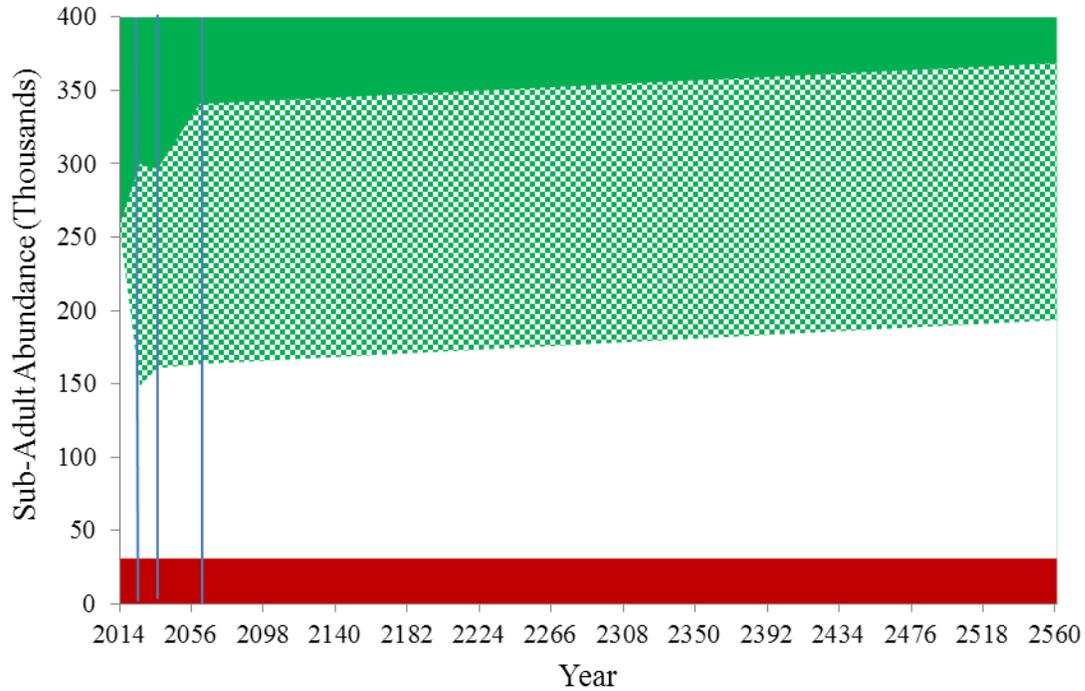


Figure 20. Performance measure scenario and checkpoints for white sturgeon sub-adult abundance. The interface between the green and the green checked zone is the projected desired status line. That is, the modeled population number with a sustainable 16% exploitation rate and current estimates of egg-to-age-1 survival and pinniped predation rates. The interface between the green checked and white is the 16% and lowest observed survival rates. The interface between white and red is the conservation status. Values in solid green are in the desired healthy and harvestable zone, those in the green checked the healthy but not fully harvestable zone, those in white zone are not healthy and those red are in the conservation status zone. Vertical lines indicate checkpoints. The first checkpoint (3 years) is at 2014 (and is the y-axis), additional checkpoints are in 15 years (2026), 25 years (2036), and 50 years (2061).

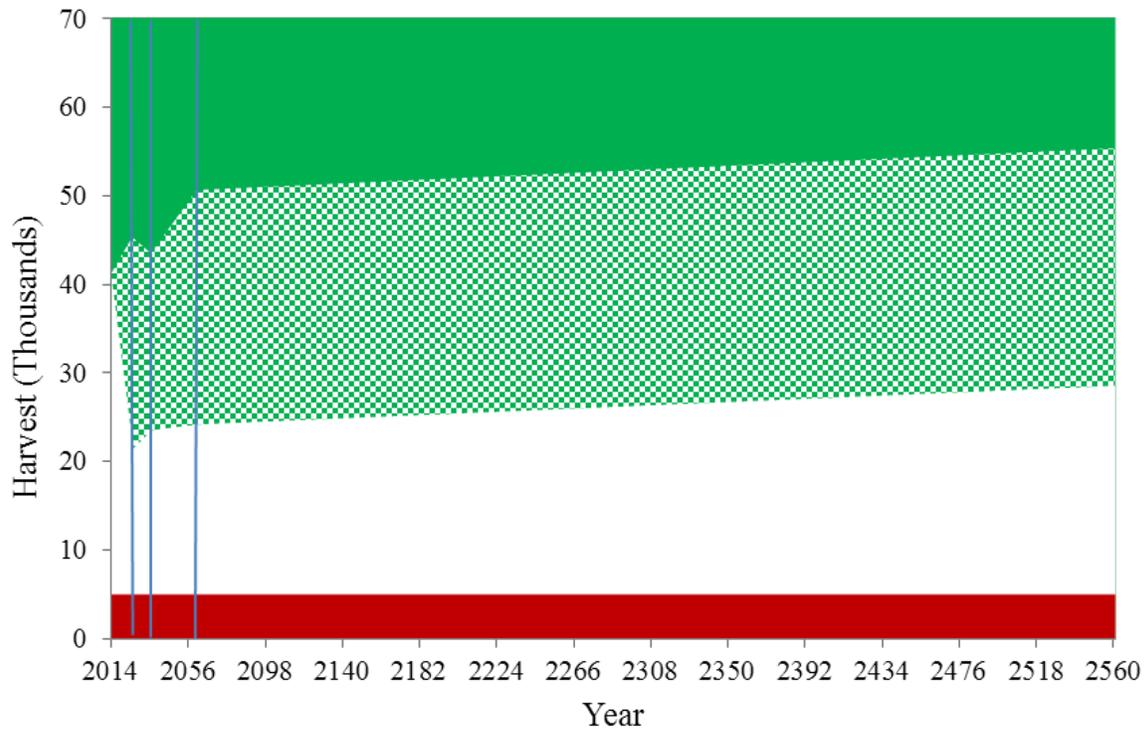


Figure 21. Performance measure scenario and checkpoints for white sturgeon sub-adult harvest. The interface between the green and the green checked zone is the projected desired status line. That is, the modeled population number with a sustainable 16% exploitation rate and current estimates of egg-to-age-1 survival and pinniped predation rates. The interface between the green checked and white is the 16% and lowest observed survival rates. The interface between white and red is the conservation status. Values in solid green are in the desired healthy and harvestable zone, those in the green checked the healthy but not fully harvestable zone, those in white zone are not healthy and those red are in the conservation status zone. Vertical lines indicate checkpoints. The first checkpoint (3 years) is at 2014 (and is the y-axis), additional checkpoints are in 15 years (2026), 25 years (2036), and 50 years (2061).

Hatchery supplementation, which could in theory also be employed to change population abundance trajectories, would require substantial amounts of time and resources to bring on-line. These limitations, combined with our current estimates of abundance and productivity and questions regarding the genetic impacts artificial sturgeon production may have, restrict its usefulness as a rapid response action. Though predation reductions and hatchery supplementation efforts could be considered and evaluated as future management actions if recommended by the White Sturgeon Technical Management Team, we will not evaluate them further here.

Other potential actions exist, e.g., ensuring adequate spawning habitat through flow augmentations, or reducing stranding of early life history stages by stabilizing flows. However, though the effects of these actions are almost certainly beneficial, they are less predictable and we have not modeled potential population responses at this time. However, should responses become more calculable we will, in accordance to our adaptive management philosophy, model

potential population responses to them. We will briefly discuss the possible modeled responses to fishery management actions.

If, in the future, the population does not behave as currently expected, .e.g., recruitment is less than expected and at a checkpoint sub-adult or adult abundance is found to be in the healthy but no fully harvestable, unhealthy, or conservation status zones, immediately reducing harvest rates can have a dramatic effect (Table 21).

**Table 21.** Summary of status checkpoints for adult and sub-adult abundance metrics if exploitation were reduced to 10.8% or halted.

Checkpoint	Adults		Sub-Adults	
	10.8%	0%	10.8%	0%
15 years	7,750	13,500	171,050	171,750
25 years	12,125	26,525	207,650	329,000
50 years	18,050	40,600	257,250	488,450
500 years	21,350	42,650	296,000	534,800

If recruitment and predation were worse than currently estimated and the exploitation rate were reduced from the currently modeled sustainable rate of 16% to 10.8% (that rate associated with  $SSB_{40}$ ), the modeled population response in 15-500 years is an estimated 125 – 180% increase in the adult population over the healthy but not fully harvestable trajectory. If in the same vital rate scenario was played out with all harvest suspended the modeled population response in 15-500 years is an estimated 215 - 350% increase in the adult population over the healthy but not fully harvestable trajectory. Modeled sub-adult abundance behaves similarly to that as described above for adults (Table 21). Furthermore, if we find ourselves at a point where both abundance and productivity are nearing conservation status, reducing harvest rates can move the area for population concern farther away (Figures 17 & 18). While not an optimal solution, recalling that for the population to fully be at desired status it needs to be healthy and harvestable, moving the harvest rate does provide a time and numbers buffer while the Sturgeon Technical Management Team and fisheries managers determine a corrective course of action.

It is entirely possible that other management actions or strategies may become available in the future. Consistent with our adaptive management framework, should novel or promising techniques or strategies emerge, the White Sturgeon Technical Management Team may elect to evaluate and implement them in their regular review of the lower Columbia River white sturgeon population segment.

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# Section 14 Acronyms and Abbreviations

°C	degrees Celsius	NPTFRMS	Nez Perce Tribe Fisheries Resources Management Staff
CFS	cubic feet per second	ODEQ	Oregon Department of Environmental Quality
cm	centimeter	ODFW	Oregon Department of Fish and Wildlife
cms	cubic meter per second	ODHS	Oregon Department of Human Services
COSEWIC	Committee On the Status of Endangered Wildlife In Canada	OR	Oregon
CREST	Columbia River Estuary Science Team	OSP	Oregon State Police
CRITFC	Columbia River Inter-Tribal Fish Commission	OSY	Optimum Sustainable Yield
CPUE	catch per unit effort	PCB	Polychlorinated biphenyl
CRkm	Columbia River kilometer	PDO	Pacific Decadal Oscillation
DDT	dichlorodiphenyltrichloroethane	PFMC	Pacific Fisheries Management Council
DPS	Distinct Population Segment	PIT	Passive Integrated Transponder
EPA	United States Environmental Protection Agency	POST	Pacific Ocean Shelf Tracking system
ESA	Endangered Species Act	PVA	Population Viability Analysis
ESU	Evolutionarily Significant Unit	QET	Quasi Extinction Threshold
°F	degrees Fahrenheit	rkm	river kilometer
F	Instantaneous Fishing Mortality Rate	RM	River Mile
FCRPS	Federal Columbia River Power System	S	Annual Survival Rate
FL	Fork Length	S <sub>1</sub>	Egg to age-1 survival rate
FPC	Fish Passage Center	SE	Standard Error
ft.	feet	SMU	Species Management Unit
GIS	Geographic Information System	SOR	System Operation Request
Ha	Hectare	S-R	Stock-Recruit relationship
HRPUE	harvest rate per unit effort	SSB	Spawning Stock Biomass
IPC	Idaho Power Company	TL	Total Length
ISAB	Independent Scientific Advisory Board	TMT	Technical Management Team
kcfs	thousand cubic feet per second	UCWSRI	Upper Columbia White Sturgeon Recovery Initiative
kcms	thousand cubic meters per second	USACE	United States Army Corps of Engineers
kg	kilogram	USFWS	United States Fish and Wildlife Service
km	kilometer	USGS	United States Geological Survey
lb.	pound	WA	Washington
LCFRB	Lower Columbia Fish Recovery Board	WDFW	Washington Department of Fish and Wildlife
LCR	Lower Columbia River	WDOE	Washington Department of Ecology
LCREP	Lower Columbia River Estuary Partnership	WSTAC	White Sturgeon Technical Advisory Committee
M	Instantaneous Natural Mortality Rate	WUA	Weighted Useable Area
m	meter	W <sub>r</sub>	Relative Weight
m/s	meter/second	Z	Instantaneous Total Mortality Rate
MSU	Montana State University		
NASQAN	National Stream Quality Accounting Network		
NFCP	Native Fish Conservation Policy		
NMFS	National Marine Fisheries Service		
NPCC	Northwest Power and Conservation Council		

## Section 15 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 oxyrinchus**—Scientific name of the Atlantic sturgeon

**Acipenser transmontanus**—Scientific name of the white sturgeon

**age-0 indexing activities**—Indexing activities 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

**benthic**—Of or relating to or happening on the bottom under a body of water

**bioaccumulation**—The process by which substances accumulate in the tissues of living organisms; used especially in regard to toxic substances, such as pesticides, that accumulate via a food chain

**biotic factor**—the living things present in the environment that shape an ecosystem.

**broadcast spawner**—An organism that releases eggs or sperm directly into the water column during reproductive activities for external fertilization

**broodstock**—The group of sexually mature white sturgeon available for breeding

**buccal cavity**—The oral cavity that opens to the outside at the lips and empties into the throat at the rear; and containing structures for chewing and tasting in higher animals

**bycatch**—Incidental or unintended catch of non-target species.

**Carcharodon carcharias**—Scientific name of the great white shark.

**chironomid**—small two-winged mosquito like fly lacking biting mouth parts; a member of the midge family of insects

**chromosome**—A threadlike strand of DNA in the cell nucleus that carries the genes in a linear order

**chlorinated pesticides**—Pesticides that have been shown to be hormone disrupters and cancer causing agents in vertebrates, e.g., DDT

**clupeid**—A member of the family Clupeidae, the herrings, shads, sardines, etc.

**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

**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

**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

**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

**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

**genome**—The total complement of genes contained in a cell; commonly used to refer to all genes present in one complete set of chromosomes

**habitat suitability indices**—A numerical index that represents the capacity of a given habitat to support a selected species

**heterozygosity**—The presence of different alleles on one or more genes

**homogeneous**—Uniform structure or composition throughout, e.g., a genetically homogenous population

**Homo sapiens sapiens**—Scientific name of humans

**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

**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 are 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

**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 interparity**—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  $W_r = W/W_s * 100$ , where  $W_r$  is the calculated relative weight,  $W$  is the weight of the fish you are measuring and  $W_s$  is the standard weigh of a fish of that length in the population

**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”

**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

**thiaminase**—A naturally occurring enzyme commonly found in members of the herring family

**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

# Appendix A. Conversion Factors

<b>Multiply</b>	<b>By</b>	<b>To obtain</b>
centimeter (cm)	0.3937	inch (in)
cubic foot per second (cfs; ft <sup>3</sup> /s)	0.0283	cubic meter per second (m <sup>3</sup> /s)
feet	6	fathom
millimeter (mm)	0.03937	inch (in)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
liter (L)	33.82	ounce, fluid (fl.oz)
liter (L)	2.113	pint (pt)
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)
meter per second (m/s)	3.281	foot per second (ft/s)
kilogram (kg)	2.205	pound (lb)
thousand cubic feet per second (kx ft <sup>3</sup> /s)	0.0283	one thousand cubic meters per second (kxm <sup>3</sup> /s)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32) * 0.55556$$

Fork Length (FL) of Lower Columbia River white sturgeon may be converted to total length (TL) as follows:

$$\text{TL} = 1.11 \times \text{FL}$$

# **Appendix B. Documentation of the Oregon Department of Fish and Wildlife Population Viability Analysis Model**

## ***Model Selection***

As part of the ODFW's process for developing the Lower Columbia River White Sturgeon Conservation Plan, we constructed an age-based population model. Our model allowed us to interpret the relative effects that various impacts on white sturgeon in the LCR might have, and the corresponding management actions that might be taken as a result. We also used this tool to evaluate long-term implications and effects of various white sturgeon limiting factors and threats.

We considered multiple modeling platforms prior to constructing the model. Overall, our goal was to create a tool that would be useful in describing the probability of persistence given a set of input variables. The model would also be useful for manipulating those variables to allow for inferences about the relative affects of multiple unknown or poorly understood factors. In order to accomplish these goals, we envisioned that a suitable model would need to incorporate a majority of the following aspects: vital rates and population dynamics, habitat condition, variability in population response, model complexity, and the model's ability to help us understand and explain population responses.

The model should simulate specific population dynamics characteristics and parameters that we believe are important to white sturgeon productivity and viability. A suitable model should be flexible in application of age and growth information to appropriately represent our understanding of growth rate changes by age, size, and life history stage, and the high degree of variability among individuals. The model should incorporate our knowledge of white sturgeon sex ratios and iteroparous maturation rates. The model should allow us to explore the potential effects of density dependence on mortality, growth, and productivity. The model should allow us to examine spatial structure and dispersal; specifically it should allow us to incorporate estimates or theoretical values for out migration rates. An ideal model would also allow us to simulate potential genetic effects associated with low abundance or with hatchery fish releases.

Environmental limiting factors for white sturgeon viability and productivity likely include reduced habitat condition associated with anthropogenic development. The model should allow us to address reduced productivity and survival associated with habitat loss, hydrosystem operations, and climate change.

The model should handle variability by simulating stochasticity and covariance, and it should allow us to explore the potential interactive effects of multiple variables.

In selecting a model we considered its overall complexity and the availability of essential data. We examined existing model templates and software from throughout the region and used for sturgeon species in other areas. We needed a model we could modify using available expertise and we considered if data needed to parameterize the model were available or if they would need to be drawn from similar species or based on theory.

Finally we needed the model to be instructive. It should help us understand the relative contribution of limiting factors and threats and be informative for future harvest management decisions.

Several model types were considered and evaluated according to these criteria. Following is a general description of those models and reasons for why they were or were not chosen for the final model.

### Abundance & Productivity Conservation Curves

Largely salmon-based and do not allow for extensive manipulation of variables as needed for this task. Concerns were expressed about the ability of these models to adequately describe the unique characteristics of sturgeon populations. No ability to model individuals or varying length-at-age.

### Age-structured population simulation

Flexible structure for the purposes needed. Concerns expressed about known difficulties in aging white sturgeon and effects that might have. No ability to model individuals.

### Individual based Bioenergetics

Extremely flexible platform. Concerns about technical difficulties and staff expertise in constructing models, as well as intensive data needs that outstrip available information.

### Life-Tables and Elasticity Analysis

Flexible and simple technique with relatively simple data needs. Less utility in exploring various scenarios. Concern about potential for unclear interpretation of results.

### Harvest Management Approaches

Simple technique with relatively simple data needs. Concern about harvest-centric approach and lack of inclusion of other limiting factors in the model.

### Weight of Available Evidence

Very flexible and suited to data poor situations. Concern about lack of scientific rigor and potential subjective conclusions.

## ***Population Dynamics and Background***

Constructing population dynamics models to reflect natural populations is inherently problematic, even when adequate data is available and the dynamics of the population are well understood. This is especially true with white sturgeon due to the complexity of their life history strategies, and their long lifespan.

White sturgeon utilize a periodic reproductive life history strategy (Winemiller and Dailey 2002). Adults mature at a late age, females produce large numbers of eggs, and adults do not spawn annually. Because of the unique life history strategies of white sturgeon, population modeling techniques and population viability metrics developed for other species are difficult to adapt to sturgeon species. For example, stock-recruitment functions for periodic strategists in general and white sturgeon in particular are difficult to define, and may in fact not exist in the classic sense (Whitlock 2007). In shorter-lived species, such as Pacific salmon, the spawning stock may consist of one to three identifiable age classes spawning in any given year. Although fecundity of female spawners for salmon is linked to size and age, the difference between the fecundity of fish of different ages is likely to be relatively small. In such cases, the number of total offspring produced by the total spawners in any given year may be well correlated to numbers of offspring, and may be definable using gross-scale population parameters such as number of spawners and number of offspring returning in some later year.

White sturgeon spawn repeatedly over the course of their mature lifetime. For females, which typically mature at around 25 years of age, this can result in a period of up to 75 years of total reproductive viability. Given an average three year spawning cycle and a potential reproductive lifetime of 75 years, a female may spawn 25 times during her lifetime. It should be noted that although the potential longevity for white sturgeon is high, most probably do not attain the maximum known age (Sulak and Randall 2002).

Fecundity in white sturgeon is high compared to other species, and is strongly correlated to fish size. A 25-year-old female white sturgeon may produce 250,000 eggs. If the fish survives to age 70, the same fish may produce >1 million eggs. Because the reproductive value, in numbers of eggs alone, is so much greater for larger fish, total production of offspring may vary greatly for a population depending on the size/age structure of the spawning stock in any given year. Without detailed knowledge regarding size and age distribution, sex ratio, the abundance of the population, and the inter-annual spawning frequency of individual fish, it is extremely difficult to identify how many offspring are produced in any given spawning season from a given number of adults, even if the absolute population size is well known.

In addition to difficulties in estimating total production of offspring, quantifying survival of offspring is also extremely difficult. Growth rates among individuals are highly variable, even among full-siblings in hatchery settings. White sturgeon are also difficult to age from calcified structures, leading to errors in estimates of size-at-age (Rien and Beamesderfer 1994). These errors tend to increase with the age/size of the fish, meaning that the larger a fish becomes, the more apt it is to be incorrectly assigned to an increasing range of potential annual cohorts. The variability in growth and size at age makes cohort analyses difficult, either by aging or length-frequency techniques. The combination of size-specific and highly variable fecundity and highly variable growth of individual fish, as well as difficulties in adequately sampling white sturgeon populations make development of a stock-recruitment curve problematic.

White sturgeon are difficult to sample effectively for assessing population dynamics. The large range in sizes between life history stages makes population assessment especially sensitive to issues of gear vulnerability in sampling. Some stages, for instance juveniles less than 54 cm fork length and exceptionally large adults, are difficult to collect at all, and these gear selectivity issues make representative sampling problematic. White sturgeon also inhabit diverse habitats in large river systems, which can be inherently difficult to sample representatively or at all.

the long lifespan of white sturgeon also presents problems in gathering basic population information. Given the long life, late maturity, and long generation times, monitoring population responses requires long timeframes. Standardized stock assessment work on white sturgeon in the lower Columbia has been ongoing since at least 1987. The most recent full stock assessment survey available at the time model development began was from 2008. Over the course of the plan development, some parameters were able to be updated, while others were not. Thus, although 21 years of stock assessment data are available, juvenile fish sampled in the very first surveys may only now be reaching maturity. Given vulnerability to currently utilized sampling techniques, even if juveniles sampled in 1987 spawned successfully in 2008 and offspring survived, those offspring would likely not be detected until several years later.

With the exception of age-0 indexing surveys begun in 2004, and a few surveys conducted in the 1980s for population estimation which sampled a large size range of fish, the majority of recent population assessment work has focused on estimating abundance of fish at or near the legal size

limit for harvest fisheries. Given limited resources, estimating the abundance of fish entering fisheries has been the focus of these studies. However, this inherently focuses tagging and assessment efforts on fish that are between about 9 and 19 years old, and abundance estimates for fish outside this range are generally not available.

If vital rates and abundances for fish 9 to 19 years old were known with certainty, the available information could be used to forecast or hind-cast population size by age and to assess year-class strength. Even if this were done, the bounds of the information available would increase only slightly, and would not encompass multiple generations, due to the comparatively limited time series of available data. A population estimate for age 0 fish in 1968 could be hind-cast from age 19 fish in the 1987 assessment, but no information on other age classes would be available for that year, and verification of the estimate would be impossible. A forecasted estimate for age 30-40 fish in 2008 can also be derived by projecting 1987 data for age 10-20 fish, and if abundance estimates in 1987 and 2008 were certain, the 2008 estimate could also be used to verify vital rates for some age classes. However, due to natural variation, sampling limitations, and estimation uncertainties, as well as the aging difficulties and variable growth rates, abundances in these age classes are not fixed from year-to-year, and do not necessarily reflect real variability in abundance. Because of these issues, fisheries managers have historically viewed these estimates as indexes and have considered several years' abundance data in combination in order to assess the population trends for white sturgeon, rather than treating estimates in each year as absolute abundances. The relatively short time series of abundance estimates (compared to the generation time of white sturgeon) and small range of ages represented in each stock assessment is insufficient to allow for construction of the full size/age distribution of the population in any given time period at this time.

Additional uncertainty surrounds the estimation of vital rates. Survival by age or size is largely unknown, although some estimates have been made. Survival of eggs to age 1 is unknown for white sturgeon, and has only been calculated as an equilibrium value – the value needed to make population models based on fit the data available.

Survival rates for fish older than age 1 have been derived from catch curves, although uncertainties in gear vulnerability and age assignment have lead to high variability between rates derived from different data sets. Survival rates have also been estimated using rules of thumb, such as: 1) Pauley's (1983) equation for mortality based on latitude, average annual temperature, and age at maturity, 2) Chen and Watanabe's (1989) equation for mortality based on fish weight, and 3) instantaneous mortalities based on parameters of the fitted Von Bertalanffy curve.

With the exception of the Chen and Watanabe method, these methods only allow for calculation of the average instantaneous mortality rate across all ages in the population, rather than for each age or size class. Because of the long life span and high fecundity of white sturgeon, small changes in age-specific survival rates can have large affects on the outcomes of population modeling exercises. Population averages and even stage-specific survival rates may be insufficient to describe population dynamics under these conditions.

Because of the known difficulties in aging white sturgeon (Rien and Beamesderfer 1994), we examined the utility of using a size-based model. Such a model has been used in recent years to help describe population dynamics in white sturgeon populations in Columbia River reservoirs (Chapman and Jones 2010). Growth increment data from tagging studies in the lower Columbia River are available. Recaptures were compared to initial tagging data to estimate growth over

time. Average annual increments for each size class were calculated, and a probability transition matrix was used to estimate the progression of starting abundances to larger size classes over time. When identical vital rates were incorporated, the results of this model were not substantially different than the age-based model over the modeled period of years. Given the prevalence and familiarity of age-based models in the literature, and the improved tractability of model construction for the age-based version, we opted to use the age-based model, despite its acknowledged shortcomings, for this exercise.

## ***Model Parameters and Inputs***

### **Stock recruitment**

The lack of a defined stock-recruitment function led us to develop alternative methods to calculate productivity of the population. Given the concerns expressed above regarding incorporation of size/age structure in the population dynamics, we felt that arbitrarily fitting a stock-recruitment function was not appropriate, and development of a rate to quantify how many offspring survive from spawning to age 1 was a suitable alternative. In this case, survival actually incorporates many aspects of production, and includes all losses incurred between the time when eggs are mature and the female spawns until the spring of the following year. Any losses from lack of fertilization, predation, or mortality in the egg, larva, or age-0 stages are implicitly included. For simplicity, we call this rate **egg-to-age-1 survival**, or  $S_1$ . Development of this rate allows for simplification of the model such that the number of eggs produced by spawning females can be estimated by the number of fish mature at each age, the proportion of mature fish that are females, and the proportion of females that are expected to spawn (spawning periodicity) in any given year. This proportion is multiplied by the age-specific fecundity and all values are summed to estimate total egg production in each year. The total egg production is then multiplied by  $S_1$  to estimate the number of age 1 fish in the subsequent year.

Due to the lack of information on the full size/age-structured abundance discussed above, identification of the number of spawners in one year and the number of age 1 fish surviving into the next were unavailable. In lieu of this information, we used the model itself to calculate both of these parameters for each set of stock assessment data available. This technique is similar to the approaches taken by several authors when attempting to quantify  $S_1$  (Tate and Allen 2002, Jager et al 2001, Pine et al. 2001). Although this approach is a labor-intensive method of fitting parameters, it allowed us to estimate  $S_1$  that fits the data available. However, because it is linked to model outputs of various other parameters,  $S_1$  is influenced by the uncertainty around the remaining vital rates in the model. In short, the rates fit the data available, but that does not necessarily indicate that the estimates of  $S_1$  are biologically correct.

Because of the hind-casting required to calculate  $S_1$ , variations in assumed annual survival among age classes result in similar variations in  $S_1$  calculated by the model. If natural mortality is high over a series of ages, and surveys in one year showed X number of fish of age 10, then 10 years earlier, there would have been X/survival number of fish of age 0. In order to achieve that number of age 0 fish in that year, a specific  $S_1$  would be required. The  $S_1$  values were estimated as the median of several of these hind-cast results for several stock assessment data sets, and are unique to each assumed survival curve (for fish age 1 and older) in the model.

### **Survival (age 1+)**

We selected three methods for expressing survival for fish older than age-0. Any of the three can be selected during the modeling process to compare results under different assumptions.

Survival option 1 is based on published values from Beamesderfer et al (1995) for juveniles and sub-adults (0.787 annual survival for juveniles and 0.90 for sub-adults), and an annual survival rate of 0.95 for adults. This option was used for all final model runs, although the other options were examined during sensitivity analyses. Survival option 2 is a flat annual survival rate of 95% for fish of all sizes. The third method is derived from Chen and Watanabe (1989) and is calculated based on average weight by age. This survival rate is a curvilinear function with the lowest survival at age 1 increasing to an asymptotic maximum at age 100.

## **Predation**

Although predation on white sturgeon by sea lions (California and Steller) is known to be extensive downstream of Bonneville Dam, estimates of total predation are unavailable. At this time, seasonal observation data from the USACE is the only available information regarding predation mortality of white sturgeon. As far as we are aware, there are also no bioenergetics or consumption rate studies available that could be used to estimate overall predation of white sturgeon given an assumption of total pinniped biomass or other measure of pinniped abundance. The states of Oregon and Washington have utilized log books for documenting incidences of predation downstream of Bonneville Dam, but the methodology is not suited to expansions for estimating total predation. Log book entries indicate that predation on white sturgeon by both California and Steller sea lions occurs in the entire river between the mouth and Bonneville Dam. Anecdotal reports also indicate some predation by harbor seals. Predation by California sea lions is believed to occur at a lower rate (white sturgeon taken per day per pinniped) than predation by Steller sea lions, but California sea lions are also more abundant. Although the total number of white sturgeon taken by sea lions annually is unknown, it is commonly believed to be large enough to pose some risk to the white sturgeon population. Because of the potential importance to the PVA risk analysis, we used available information to generate an estimate of total annual predation for use in the model.

The total number of California and Steller sea lions in the Columbia River is currently unknown. The only available estimates are from a 2006 survey by WDFW that estimated a total abundance of about 1,200 California and 1,000 Steller sea lions (<http://wdfw.wa.gov/wlm/sealions/questions.htm>). River-wide white sturgeon predation rates are unknown.

Given the lack of data, we used the USACE observation data to estimate total predation in the entire river downstream of Bonneville Dam (Tackley et al. 2008). Observations of Steller sea lions in the observation area have generally increased annually. From 2005-2009, an average of five additional individuals were counted in the USACE observation area each year. California sea lion numbers in the observation area appear to have stabilized and may be declining somewhat. In 2009, the USACE noted a maximum number of 26 Steller sea lions in the observation area. During the same timeframe, ODFW Columbia River Management personnel observed 44 individual Steller sea lions hauled out on Phoca Rock, approximately 13 river miles downstream from Bonneville Dam. Under an assumption that the relative abundances in the areas between Phoca Rock and the observation area and in the observation area itself are consistent from year-to-year, we calculated that approximately half of the Steller and California sea lions present from Phoca Rock upstream to Bonneville Dam would be observed in the USACE observation area.

In addition to doubling the current USACE estimates of Steller sea lion abundance, we estimated that the total number of Steller sea lions would continue to increase by ten animals per year (five

additional in the observation area and five additional between the observation area and Phoca Rock). We limited the increase in abundance to a maximum of 100 Steller sea lions, under the assumption that at that point the density of Steller sea lions in the area would be high enough to discourage additional animals from moving into the area. Under this assumption, the number of Steller sea lions would climb to 102 animals by 2014, and would cease to increase beyond that point. We assumed no increases in river-wide abundance of pinnipeds; assuming that if 102 Steller sea lions were present in and around the observation area, another 898 would be to be at large in the remainder of the river. We did not differentiate between predation rates of California sea lions present inside and outside of the USACE observation area, and therefore did not segregate the estimated 1,000 animal California sea lion population into different areas of occupancy.

We used the 2007-2009 USACE observation data to calculate a daily rate of white sturgeon consumption per animal. This rate was calculated separately for California and Steller sea lions, and separately for Steller sea lions inside and outside of the area between Phoca Rock and Bonneville Dam. For Steller sea lions in the USACE observation area, the average consumption per day was 0.44 white sturgeon per animal. Because white sturgeon densities are known to be high in the observation area during the timeframe sea lions are present, the Steller sea lion rate of consumption for the observation area is likely higher than the rate of predation for the remainder of the river. We assumed that the daily predation rate for Steller sea lions downstream of Phoca Rock was twice the estimated daily predation rate of California sea lions in the observation area. This yielded a rate of 0.01 white sturgeon per day per Steller sea lion downstream of Phoca Rock. Daily predation rates by California sea lions in the observation area averaged 0.005 per animal per day. We chose to apply this same rate to all California sea lions, regardless of the area they were occupying. Although some predation by harbor seals has been reported, we had no information on rates of predation or abundance of animals with which to generate estimates of total predation. Total numbers of white sturgeon predated by harbor seals is likely low overall and is not included in the model. Finally, we estimated total residence time in the Columbia River by both California and Steller sea lions to be 180 days each year, assuming first arrival on December 1 and departure on May 31.

Given the predation rates, sea lion residence time, and estimated abundances described above, total predation of white sturgeon from Bonneville Dam downstream to the river mouth was estimated to be 6,700 in 2009, increasing by about 800 fish per year to a maximum of 10,600 in 2014. Under the assumptions described above, total predation is expected to remain at 10,600 per year through the remainder of the 500 years modeled in the PVA.

In the 2008 and 2009 USACE predation reports, sizes of fish predated in the observation area appear to be consistent with the overall abundances by size/age class. Accordingly, we originally apportioned out predation by age according to relative abundances in each age class. A further modification was later made to incorporate a size-selectivity function to allow the model to alter relative predation among size classes at varying population size distributions. Because the maximum predation of 10,600 was reached by 2014, we did not incorporate a gradual increase in predation from 2009-2014 in the model itself, but just used 10,600 as a standard input for all years in the model.

Because we did not incorporate any density dependent mortality mechanisms in the original model development, under some assumptions the model runs indicated unlimited exponential increases in population size over the course of the modeled timeframe. This is unrealistic and we

opted to create a maximum population size, based on total biomass in the population, which could not be exceeded in the model.

Because the Columbia River population was relatively unexploited prior to the 1880s, we assumed that the biomass present at that time represented the maximum that could be sustained in the lower Columbia River. During the late 1880s, harvest increased dramatically from year to year over a very short period of time, and then plummeted, leading to the extended closure of all white sturgeon fisheries in the lower Columbia River for decades (Craig and Hacker 1940). The period used was from 1889-1899. Over this time period, a total of 18.6 million pounds of white sturgeon were reported (Craig and Hacker 1940). Some years, however had no reported landings. Because fisheries were likely ongoing for the entire period, we filled in landings for missing years using a fitted log-normal curve ( $r^2 = 0.98$ ). We treated the total biomass removed in the fisheries from 1889-1899 as an estimate of the equilibrium population biomass. The total harvest over the period of record was summed and the estimated average size data from that timeframe was used to calculate the total biomass removed in the fisheries. Information in Craig and Hacker (1940) indicates that harvest in this period included few small fish. Therefore, we used an estimated age distribution for an equilibrium population derived from the model to interpolate biomass of younger age classes from the biomass of older age classes harvested. We then set the biomass of fish of all ages as the maximum carrying capacity in the model.

In the model, a curvilinear function gradually increases annual natural mortality rates on all age classes as total biomass in the population approaches the maximum. As a result, the total biomass is never allowed to exceed the historic estimated biomass for the population. While this function fits the historical biomass and age distribution estimates, it was not structured to mimic any specific density-dependent mechanisms.

## **Exploitation**

Estimates of annual fishery exploitation rates for use in modeling harvest impacts were derived from tag recoveries. We analyzed tagging data from the stock assessment program to estimate the exploitation rates. For this program, tags are released in May and June and are recovered over the course of the following year. Recoveries of tags in fisheries for one year following release of annual tag groups were expanded by the sampling rates in each fishery. The number of tagged fish harvested was divided by the number of tagged fish available at large to estimate the exploitation rate over the one year period.

Tagged sturgeon may grow markedly during a one year period, and harvest fisheries are structured around specific size slots. Thus, incorporating some growth of fish into and out of legal size limits is necessary when calculating exploitation rates over a one year period from tagging data. To do this, we used the 10<sup>th</sup> percentile of the size at tagging for all fish recovered within 1 year to derive the lower size limit for tags from the original tag group that would comprise the at large tags available in the fisheries. We used the maximum size at tagging for all fish recovered within 1 year to define the corresponding upper bounds. Additionally, we assumed a tag loss over the one year at-large period of about 10.5%, based on past tag retention estimates.

## Catch and Release Mortality

We incorporated catch and release mortality in the model. This is applied to all fisheries conducted in the modeled population. The rate at which non-retained fish are handled is assumed to be directly proportional to the target exploitation rates specified in the model. This is a simplification of what likely occurs in the fishery, and likely does not include all catch-and-release that occurs because it only incorporates fish caught and released in pursuit of fish for harvest, not directed catch-and-release fishing. Fish caught and released are assigned a mortality rate of 2% (Whitlock 2007). Under these assumptions, and the recent average exploitation rates, this would equate to a mortality of 0.4% of all fish smaller and larger the legal-size categories.

In addition, the model is capable of accounting for catch-and-release angling targeted at over-legal-size fish in a specific area downstream of Bonneville Dam. This area remains a popular fishing destination and large numbers of oversize fish are handled in the area annually despite progressively more restrictive fishing regulations being enacted over the last decade. Using recent fishery data, we estimated that up to 20% of oversize fish may have been handled in this area in some years. Assuming a maximum of 20% of the adult population is handled, and a 2% post-release mortality rate, an estimated 0.4% of oversize fish would be estimated to die as a result of catch-and-release fishing in this area. This would be in addition to mortalities incurred from catch-and-release of oversize fish during fisheries targeting legal-sized fish. Under the above assumptions, this would equate to a total mortality of 0.8% (0.4% for catch-and-release during retention fisheries and 0.4% for catch-and-release in targeted oversize fishery) of all over-legal-sized fish.

## Extinction Thresholds

In determining criteria for extinction risks, we tried to model our derivations on salmonid models currently in use. These largely focus on risks on a generational scale. Because female white sturgeon mature at around 25 years old, generational scales for white sturgeon are composed of multiple decades. We chose a generation period of 25 years, which represents the approximate timeframe for a newly-hatched female white sturgeon to reach maturity and first spawning. Because of multiple spawning and year class overlap, a precise generation time is neither available nor necessary. For an extinction threshold value, we chose to use the lowest number of adult spawners that have been estimated in any of the stock assessment surveys in the Columbia River. In 2006, 250 adult fish were estimated for the population in Bonneville Reservoir (Weaver et al. 2008). That number has since increased (ODFW unpublished data). Thus, 250 adult fish was chosen to represent the level at which, if the population continued to decline, we would have maximum uncertainty of what would occur in the future. Based on this, we set the quasi-extinction threshold (QET) at 250 adult fish for a period 25 years or longer in a row. If the population of spawning-sized fish drops below 250 per year for 25 years or longer, the population is assumed to be functionally extinct.

Under some combinations of model assumptions, population size can reach 0 before the population reaches the QET definition of 250 fish or fewer for 25 sequential years, and in these situations, the population is still considered extinct.

Few studies have quantified extinction thresholds for sturgeon populations. A recent article by Schueller and Hayes (2010) assessed the sensitivity of lake sturgeon population dynamics and genetic health to varying demographic parameters. Their results suggested that extinction risk

and inbreeding were greatly reduced in populations with a starting abundance of 200 fish or greater.

### **Stochasticity**

We wanted the model to be able to reflect some level of stochasticity in projecting viability risks. Because recruitment functions in many fish species, including sturgeon, are known to be correlated to environmental variables, we added stochasticity by incorporating a river flow variable. This variable operates by altering the median value for  $S_t$  proportionally to median river flow values. We examined 40 years of available flow data (mean daily flow from May-July) for Bonneville Dam outflow. The patterns of flow over the 40-year period were duplicated multiple times to create a long term time series from which random blocks of years could be drawn. A random function selects a start year in the time series in which the model will begin. All years after that point follow the original year according to the original patterns. We then scaled  $S_t$  directly to the flow pattern providing a randomly selected, but co-varying, range of survival rates for the model. The model is then run for 500 years, and then a new random flow year is selected and the process is repeated.

Appendix Table B-1. Default parameters and vital rates incorporated into the PVA model.

Parameter	Value	Comment	Source
Immigration	1,000	from Bonneville Reservoir	Staff selection
K (kg biomass)	27,280,692	Estimated Carrying Capacity (kg)	Derived from peak harvest information, expanded for smaller fish not included in harvest
Starting Pop Size	1,286,922		2010setline -based population estimate
Starting Year	2010		
Survival (age 1+)	curve, stepped, or constant		Curve = Chen and Watanabe size/mortality, stepped = Beamesderfer et al 1995 (default), constant = 95%
N Predation	10,600		See Predation description
Max Predaton Rate	100%	cap on % of vulnerability of fish that can be predated	Allows predation to be limited (<100%) or incorporate predator trap (100%)
Stages	11	subadult age	
	25	adult age	
Years in Model	500		
Exploitation Rate			
variable		Catch and release of sublegals	CnR mortality times fishery slot 1 exploitation rate
variable		Fishery slot 1	Recent-year average from tag-based ER estimates
variable		Fishery slot 2	Recent-year average from tag-based ER estimates
variable		Catch and release of oversize	CnR mortality times fishery slot 1 exploitation rate <u>plus</u> target oversize CnR mortality if specified
CnR mort	2%	Assumed post-release mort per fish	Staff selection; Whitlock 2007 = 2.1%
Gorge OS target allowed?	Y/N	Is Oversize target in Gorge allowed?	If specified "Y", additional CnR mortality based on proportion of oversize fish handled and CnR mortality rate
Age & growth			
	310.000	L infinity	Beamesderfer et al 1995
(VBGF only for age >29)	0.03	k	Beamesderfer et al 1995
	-2.4	to	Beamesderfer et al 1995
Len/weight	9.86E-09	wt-leng a	Calculated from landings data
	4.41E+00	wt-leng b	Calculated from landings data
	2.74E-06	std weight a	Beamesderfer 1993
	3.232	std weight b	Beamesderfer 1993
	2.1137	fl-tl intercept	Calculated from landings data
	1	fl-tl slope	Calculated from landings data
Reproduction			
% female	45%		DeVore et al 1995 (total population ratio)
female spawning periodicity (yrs)	3		Webb and Kappenman 2010 (unpublished)

fem maturity avg size	160.0	(cm)	Beamesderfer et al 1995 DeVore et al 1995
fem maturity variance	18		Beamesderfer et al 1995 DeVore et al 1995
age of scenescence	100		Staff selection
QET (sp female only)	38	(250 adult * % fem * % spawn)	See Extinction Risk description
fecundity a	0.072		DeVore et al 1995
fecundity b	2.94		DeVore et al 1995
$S_1$ (egg to age 1 survival)	0.00196		Model-derived median from 1987-2004

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## Sensitivity Analysis of Model Parameters

Because many of the vital rates and other parameters in the model are uncertain and some are not empirically derived, we conducted sensitivity analyses to test the relative effects of changes in these parameters on the model outcomes. During these analyses, individual parameters were varied but variations on combinations of parameters were not, i.e., one parameter was changed at a time.

In general, the vital rates that affect the population responses the most appear to be those that directly affect total mortality of sub-adult and adult fish (Table B-2). Direct losses of these fish, regardless of source, reduce the productivity of the population. Because we are unable to identify density dependent responses in the population at this time, compensatory responses of lower abundance are not incorporated into the population projections. If they exist, compensatory responses would mitigate the response to direct mortality. However, in the absence of clearly identified compensatory responses, the model identifies total mortality, regardless of source and in any combination, as a key driver in the persistence and productivity of the population. Survival to age 1 ( $S_1$ ) is also a sensitive parameter, although it appears to be somewhat less sensitive than total mortality. This may simply be because its effects are restricted to a single age class. Although total mortality of older fish may be more sensitive in the model, increased  $S_1$  may yield larger gains than decreased mortality in fish greater than age 1 in some cases.

Table B-2. Results of PVA model sensitivity analyses. Percentages represent the average magnitude of change of a given parameter from the base value associated with varying the model input. If a parameter other than the 30 year lambda varied by  $\leq 10\%$  with a given input change we considered the change to be not consequential (NC) in model development, for the 30 year lambda we considered a change of  $\leq 5\%$  to be not consequential.

Parameter	Starting Abundance		N Predation		% Predation		Exploitation Rate	
	x125%	x75%	x125%	x75%	x2	X0.5	x125%	X75%
Total Abundance	NC	NC	-57%	NC	-70%	NC	90%	12%
Female Spawner Abundance	NC	NC	-56%	NC	-70%	NC	93%	38%
Age-1 Abundance	NC	NC	-60%	NC	-69%	NC	90%	22%
30 Year Lambda ( $\lambda$ )	NC	NC	NC	NC	NC	NC	NC	6%
Parameter	Egg to Age 1 Survival		Immigration		Sublegal and Overlegal Catch and Release Mortality		Female Spawning Periodicity	
	x140%	x60%	10,000	0	0%	10%	2 year	5 year
Total Abundance	11%	-14%	NC	NC	NC	-27%	20%	-14%
Female Spawner Abundance	-13%	27%	NC	NC	NC	-24%	48%	-29%
Age-1 Abundance	15%	-17%	NC	NC	NC	-27%	29%	-18%
30 Year Lambda ( $\lambda$ )	NC	NC	NC	NC	NC	NC	NC	NC
Parameter	Female Size at Maturity		Survival		Senescence at age 50			
	150 cm	170 cm	Curve	Constant				
Total Abundance	NC	NC	-45%	-99%	NC			
Female Spawner Abundance	55%	-20%	42%	-90%	NC			
Age-1 Abundance	NC	NC	-45%	-100%	NC			
30 Year Lambda ( $\lambda$ )	NC	NC	NC	NC	NC			

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