Snake River

White Sturgeon Management Plan

2023-2032

Prepared by IDAHO DEPARTMENT OF FISH AND GAME

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EXECUTIVE SUMMARY

Fisheries management direction for the Idaho Department of Fish and Game (IDFG) is formalized in a document titled, Fisheries Management Plan 2019-2024: A Comprehensive Guide to Managing Idaho's Fisheries Resources (IDFG 2019). The Snake River White Sturgeon Management Plan is a complimentary but more detailed species management plan. This plan provides direction for Snake River White Sturgeon management across occupied reaches, classifies reaches into three management categories (Core Wild, Stocked, and Non-Native Range) and provides more detailed information on populations assessment, hatchery stocking and future goals on an individual reach basis.

The plan has been drafted by IDFG staff, vetted by partner agencies and the public, and considered by the Idaho Fish and Game Commission and was adopted on XX/XX/XXXX. This plan serves as the state of Idaho's policy and guidance document for management and conservation of Snake River White Sturgeon.

White Sturgeon, *Acipenser transmontanus*, are a pre-historic native species highly regarded for their biological and ecological uniqueness and prized for their recreational angling value. Due to their large size and fighting ability, catching one of these freshwater giants is a lifetime memory for many anglers. White Sturgeon range includes freshwater and saltwater habitats along the Pacific coast from Mexico to Alaska, and spawning populations are found in the Sacramento, Columbia, and Fraser river systems. In Idaho, White Sturgeon are native to the Kootenai and Snake rivers. The native range of White Sturgeon in the Snake River extended from the confluence with the Columbia River upstream to Shoshone Falls. Release of hatchery reared sturgeon has extended the range in the Snake River upstream from Shoshone Falls to Idaho Falls.

White Sturgeon are long-lived with some individuals exceeding 100 years of age. Age at first spawning ranges from around age 12 up to age 50 depending on the population. White Sturgeon in Idaho are reliant on large river habitat for all portions of their life history. Sturgeon spawn in large river systems during the spring when a combination of flow, turbidity, and temperature cue the migration and spawning behavior. Once hatched, larval and juvenile sturgeon continue to rear in large river systems till reaching adult age.

White Sturgeon have declined from historical abundances across their range, including Idaho. Historical declines are a combination of factors including overfishing, habitat manipulation, poor water quality, bioaccumulation of contaminants, and altered fish assemblages in larger river systems. However, habitat alteration and fragmentation from dam construction during 1900 – 1980 are considered the primary factor in declines in wild populations within Idaho. Dam construction and operations blocked migrations and altered flows, water temperatures, and nutrient regimes. Abundance in two of the nine Snake River reaches are stable or increasing, while the remaining reaches rely on hatchery stocking and downstream drift to maintain populations.

Currently two Snake River reaches (between Lower Granite Reservoir to Hells Canyon Dam and C.J. Strike Reservoir to Bliss Dam) support natural White Sturgeon spawning and recruitment resulting in stable or increasing populations. Populations residing in shorter river reaches and reservoirs within the Snake River require more active management such as hatchery stocking to maintain persistence as limited or no natural recruitment occurs in these shortened reaches.

The White Sturgeon hatchery stocking program developed to support Snake River sturgeon uses fertilized eggs collected in the wild (within the C.J. Strike Reservoir to Bliss Dam reach). Those eggs are hatched and reared in the hatchery then released into reaches not supporting sufficient natural recruitment. The technique of hatchery rearing eggs collected in the wild and releasing them back in the wild is known as repatriation. The White Sturgeon hatchery stocking program has also enhanced sportfishing opportunities outside of White Sturgeon native range upstream of Shoshone Falls. Since the early 1990s, White Sturgeon stocking has occurred upstream of Shoshone Falls to promote a diverse angling opportunity upstream to the city of Idaho Falls. The Snake River White Sturgeon hatchery stocking program is a collaborative effort between the Idaho Power Company and IDFG.

Snake River White Sturgeon reaches are managed under three management scenarios: Core Wild, Stocked, and Non-native Range. Core Wild reaches are designated as those that are self-sustaining with sufficient natural recruitment to maintain or increase abundance without hatchery stocking. Emphasis will be placed on maintaining environmental conditions required to support life history requirements for White Sturgeon recruitment and survival. Stocked reaches are designated as those which are managed through hatchery stocking to sustain abundance because of a lack of regular natural recruitment dues to habitat limitations (e.g. flow, water quality, fragmentation). Abundance in Stocked reaches will be maintained or increased through hatchery stocking or entrainment from upstream reaches. Non-native Range reaches, located upstream of Shoshone Falls, are managed through hatchery stocking to support White Sturgeon and provide angling opportunity. These reaches lack natural recruitment and will be supported solely through hatchery stocking.

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INTRODUCTION

White Sturgeon, *Acipenser transmontanus*, are the largest freshwater fish in North America and native to Idaho's Kootenai and Snake river drainages. They are an ancient fish species which have persisted relatively unchanged for over 100 million years. Despite the species long-term persistence, White Sturgeon populations have declined across much of the range within Idaho due to lack of natural recruitment in most reaches. The current status, as well as natural resource and recreational angling value of the species, warrants conservation consideration and planning to ensure these fish remain in healthy and fishable abundance for future generations to enjoy.

This management plan describes historical and current status of Snake River White Sturgeon populations and sport fisheries, limiting factors, objectives and strategies for population and fishery management, and identifies important information and habitat needs for future management. White Sturgeon occupying the Kootenai River drainage in northern Idaho are managed under the Kootenai River White Sturgeon Recovery Plan and not included in this document (USFWS 2019).

The Idaho Department of Fish and Game (IDFG) goal for Snake River White Sturgeon is to preserve, restore, and enhance populations capable of providing sport fishing opportunities. By statute, the IDFG manages the fish and wildlife of the state for the public (*Idaho Code* Section 36-103). The IDFG 2019-2024 Fisheries Management Plan (IDFG 2019) lists eight guiding principles governing White Sturgeon management within their historical range.

1. Habitat protection and enhancement—IDFG believes the most effective approach to maintaining healthy, reproducing White Sturgeon populations within their native Idaho range is to protect stronghold populations and intact habitat, and as is feasible, to improve habitat. We will continue to provide technical support and input to state and federal regulatory agencies on land and water management activities and proposals.

2. Population monitoring—intensive assessments of White Sturgeon abundance and size structure will occur in individual river reaches at approximately five- to ten-year intervals. Idaho Power will perform the bulk of the population census work but will be supplemented by IDFG and Nez Perce Tribe as necessary.

3. Evaluate fishing-related mortality–the effects of catch-and-release angling on White Sturgeon are not fully understood. IDFG has proposed to examine White Sturgeon angling effort and catch in relation to population status and trends for key river reaches.

4. Fishing regulations, angler education, and enforcement—IDFG will continue to provide barbless hook, catch-and-release fishing opportunity for White Sturgeon in the Snake River. In the state fishing rules, we require the use of a sliding weight along with barbless hooks. We will continue to develop and distribute information on White Sturgeon status and fishing opportunity and will promote angling and fish handling techniques that minimize mortality. Conservation officers will continue to educate the public and ensure compliance with rules on White Sturgeon fisheries.

5. Translocation—IDFG will collaborate with the Idaho Power Company (IPC) and other agency and tribal stakeholders in the translocation of wild White Sturgeon with a goal of artificially restoring some degree of connectivity between river reaches.

6. Conservation aquaculture—while the top priority of IDFG is the conservation of wild, self-sustaining populations of White Sturgeon, in reaches where natural recruitment is absent or minimal, hatchery stocking is a viable management option. In 2011, IDFG and the College of Southern Idaho in Twin Falls, Idaho signed a cooperative agreement on the limited production of White Sturgeon for management purposes.

7. Commercial aquaculture—IDFG will work with the Idaho Department of Agriculture to monitor commercial aquaculture operations with respect to importing non-native White Sturgeon into their hatcheries. Sturgeon are also regularly purchased by private pond owners for ornamental purposes in southern Idaho.

8. Mortality monitoring—IDFG and IPC have established protocols for investigating, examining, and collecting appropriate samples from mortalities when possible.

WHITE STURGEON REACH MANAGEMENT CATEGORIES

White Sturgeon management categories identified within this plan provide direction on strategies implemented to maintain sturgeon abundance within river reaches. Description of management categories of Snake River White Sturgeon reaches is provided below.

CORE WILD REACHES

Core Wild reaches are designated as those that are self-sustaining with sufficient natural recruitment to maintain or increase abundance without hatchery stocking. These reaches meet all environmental conditions required to support life history requirements for White Sturgeon recruitment and survival. These reaches represent critical sources of high natural genetic diversity relative to levels in other reaches and are key to maintaining unique genetic variation. IDFG management efforts will focus on protecting genetic integrity, habitat, and water quality to maintain natural recruitment and ensure survival sufficiently high to maintain or improve population status in these reaches. Core Wild reaches possess a wide range of ages and size classes and are capable of supporting recreational fisheries. Catch-and-release regulations will be maintained unless monitoring data indicates that more opportunity may be provided (harvest) or more restrictions (limit catch-and-release) are necessary if fishing mortality is documented as a concern.

STOCKED REACHES

Stocked reaches are designated as those which require hatchery stocking to sustain abundance because of a lack of regular natural recruitment. These populations are missing some environmental characteristic (e.g. flow, water quality, habitat) needed to meet life history requirement for completion of the White Sturgeon life cycle. Abundance in these reaches will be maintained or increased through hatchery stocking or entrainment from upstream reaches. Stocking will be used to maintain or rebuild spawning populations and support recreational fisheries in these reaches. IDFG will promote management actions to address environmental conditions that promote future natural recruitment in these reaches. As environmental conditions are addressed, stocking sturgeon will supplement these reaches with natural recruitment events. Recreational fisheries will be operated under catch-and-release regulations primarily. In the future, harvest regulations may be considered if populations abundances increase substantially, or more restrictive (limit catch-and-release) regulations may be necessary if fishing mortality is documented as a concern. Fisheries management decisions regarding regulation structure will be based on White Sturgeon monitoring information, stocking rates and survival, as well as public input.

NON-NATIVE RANGE REACHES

Non-native range reaches are those managed in Idaho outside the native range of White Sturgeon which contain adequate large river habitat to add diversity of angling opportunity. These reaches lack the environmental characteristics for natural recruitment and will be supported solely through hatchery stocking. Sport fishing for White Sturgeon could be maintained under a catch-and-release or harvest opportunity. Fisheries management decisions regarding regulation structure will be based on White Sturgeon population monitoring, stocking rates and survival, as well as public input.

CURRENT DESIGNATIONS OF IDAHO WHITE STURGEON

Management designations have been modified for this version of the White Sturgeon management plan to Core Wild, Stocked, and Non-native Range to more accurately describe management scenarios. Core Wild, Stocked, and Non-Native Range reach designations replaced Core, Conservation, and Sportfish designations respectively. This updated management plan designates two reaches as Core Wild, seven reaches as Stocked, and one Non-native Range reach.

SPECIES DISTRIBUTION

White Sturgeon are widely distributed along the west coast of North America. Documented observations have occurred from the Aleutian Islands of Alaska as far south as coastal waters of Mexico. While the occupied range covers a large geographic area, White Sturgeon are only native to a few large river systems including the Fraser, Columbia and Sacramento-San Joaquin rivers (Hildebrand et al. 2016). White Sturgeon exhibit both resident and anadromous life histories within these three systems, with anadromous life history expression increasing with proximity to the ocean. While anadromy provides opportunity for dispersal, movement of individuals among these large river systems is rare (Hildebrand et al. 2016). Genetic evaluations have identified six distinct population groups: the Sacramento-San Joaquin Bay-Delta, lower Columbia, middle Snake, Kootenai, lower Fraser (below Hells Gate), and upper Fraser (above Hells Gate; Schreier et al. 2013). Furthermore, this evaluation also highlighted genetic structuring within large river system such as the Columbia and Fraser rivers which provides evidence that prior to dam development within White Sturgeon populations, wide-ranging migration and mixing of populations were not prevalent (Schreier et al. 2013).

The historical distribution of White Sturgeon in Idaho included the mainstem Snake River (from its confluence with the Clearwater River) upstream to Shoshone Falls, the Clearwater River upstream to the North Fork Clearwater River (minimum estimate), and the mainstem Salmon River as far upstream as McKim Creek. In addition to mainstem rivers, White Sturgeon have been observed in the Middle Fork Salmon and South Fork Salmon rivers. Historically, there was an estimated 1,040 linear river kilometers (rkm) of mainstem river habitat in the Snake River drainage (including Clearwater and Salmon rivers) above modern-day Lower Granite Dam. Additionally, their range in the Snake River has been expanded outside their native range upstream by hatchery stocking, currently reaching as far as the city of Idaho Falls.

GENERAL LIFE HISTORY

White Sturgeon are a long-lived and late-maturing fish species compared to other Idaho native fishes. Typically used ageing structures (e.g.., scales or fin rays) do not provide accurate age estimates for the oldest sturgeon individuals given their cartilaginous skeletal structure; however, age may be estimated from growth rates of recaptured individuals. Using this method, Idaho sturgeon are known to exceed age-80, and potentially age-100 (Bates et al. 2014). In general, White Sturgeon age-at-first maturity ranges from approximately age-12 for males and age 15-32 for females (PSMFC, 1992); however, recent work in some slow growing populations suggest even older ages-at-maturity are possible (Bentz 2015a). Size at first maturity has been documented to range from approximately 75 to 200 cm, and females generally reach sexual maturity at older ages and larger sizes than males (Bentz and Lepla 2009, Beamsderfer et al. 1995, DeVore et al. 1995, Chapman et al. 1996).

Conditions which promote White Sturgeon spawning are only found in mainstem rivers. They migrate for varying distances in mainstem rivers to find appropriate spawning habitat. Spawning requirements for White Sturgeon are specific and include a variety of environmental and physiological requirements. Spawning occurs in mainstem rivers in higher velocity areas associated with large cobble size substrate. Spawning season ranges from February to August with the majority of activity occurring in May and June and is associated with high-flow events. White Sturgeon are iteroparous; however, an individual fish does not typically spawn every year. Female White Sturgeon typically spawn every 3-5 years (Paragamian et al. 2005), though some studies have documented longer spawning intervals of up to 10 years. In some instances, females may require multiple years to generate eggs for spawning and in other instances, even gravid females may re-adsorb eggs if environmental cues (flow, temperature) to trigger spawning are not met. White Sturgeon are highly fecund with individual females possessing up to 700,000 eggs (Wydoski and Whitney 2003). They spawn in relatively high gradient, turbulent river reaches, and larvae disperse long distances downstream in the current.

Early development of White Sturgeon occurs in close proximity to spawning locations. Fertilized eggs are negatively buoyant, adhesive, and typically attach to stream substrates near spawning areas (Wang et al 1985). Substrate size affects egg development and survival with larger substrates (e.g., cobble and gravel) providing higher survival (McAdam, 2011; Boucher et al. 2014). Egg incubation time is variable and dependent on water temperature with more rapid development in warmer temperatures. Temperatures exceeding 18°C increase egg mortality (Wang et al 1985). Post hatch, larval sturgeon exhibit a passive downstream drift phase for several days prior to free swimming (Hildebrand et al. 1999). As larval White Sturgeon begin exogenous feeding, they become more bottom oriented to maximize feeding opportunities (Brannon et al. 1985).

Juvenile White Sturgeon rear in mainstem rivers and in some instances mainstem river impoundments for multiple years prior to reaching sexual maturity. Small age-0 sturgeon have been documented to feed on a variety of invertebrate prey during early rearing (McCabe et al. 1993 and Muir and McCabe 2000). The diversity of juvenile White Sturgeon diet increases to include a variety of fish species and invertebrates as juveniles rear into older age classes

(Semakula and Larkin 1968). This diverse diet is carried on into adulthood with White Sturgeon maintaining an opportunistic feeding strategy dependent on prey availability.

White Sturgeon survival rates are known to vary by life stage; however, maintaining high adult survival rates is key to maintaining populations of this long-lived fish species. Limited information is available on survival of early life stages of White Sturgeon, though egg survival is assumed to be low. Thereafter, early juvenile sturgeon survival increases with greater size (Golder et al. 2015). Adult sturgeon survival rates have been documented to exceed 90% across multiple studies and watersheds (Beamesderfer et al. 1995, Irvine et al. 2007, Semakula and Larkin 1968). Monitoring adult survival in sturgeon populations is vital to long-term persistence as even small reductions in survival can have population-level effects considering their life history traits (e.g., long-lived, late maturing, infrequent recruitment).

STATUS OF SNAKE RIVER WHITE STURGEON

HISTORY OF SNAKE RIVER WHITE STURGEON MANAGEMENT

Population estimates and movement data of White Sturgeon from prior to the dam-building era in Idaho do not exist; however, historical abundance is assumed to have been greater based on anecdotal observations from angling in the early to mid-1900s. Historical data from downstream segments of the Columbia River can serve as a surrogate for Idaho's populations. The first significant exploitation of White Sturgeon on the Columbia River began in the late 1880s when demand for sturgeon meat and caviar ballooned on the east coast of the United States. Harvest within the fishery peaked at nearly three million kg of sturgeon by 1892 (Craig and Hacker 1938). The rate of exploitation was unsustainable, and White Sturgeon populations became depleted. Similarly, the decline of sturgeon in Idaho was thought to be partially caused by unsustainable harvest rates, though specific harvest rates were not determined.

Population declines are likely due to several factors including overfishing, habitat alteration and fragmentation, poor water quality/pollution, bioaccumulation of contaminants, and potentially from ecosystem changes associated with non-native fish and invertebrate introductions. Because of their large size and late age-of-maturity, sturgeon are particularly vulnerable to overfishing (both commercial and recreational), which primarily occurred in the late 1800s to the 1900s. Due to concerns about population trends, commercial harvest of sturgeon in Idaho was prohibited by 1943, and by 1971, even recreational harvest was prohibited. Since then, Idaho sturgeon fisheries have been managed with mandatory catch-and-release regulations.

White Sturgeon have declined for several reasons, but habitat alteration and fragmentation from dams built from 1900 to 1980 are the primary factors. Prior to dam construction, sturgeon had greater connectivity to long sections of river habitat and natural streamflow characteristics, allowing sturgeon to access all the parts of the river needed to complete their life history. In the Snake River, dams have segmented White Sturgeon populations into nine highly altered reaches, most of which no longer have the habitat needed for White Sturgeon to complete their life cycle. The diverse spawning, rearing, and feeding habitats required by White Sturgeon to complete their life history were altered by the construction and operation of dams on the Snake River. Water regulation and diversion associated with the operation of mainstem dams changed the annual, seasonal, and daily flow regimes with impacts to natural spawning of White Sturgeon. For example, load following at the Bliss Dam hydroelectric facility under certain flow conditions adversely affected White Sturgeon spawning activity and success (Lepla and Chandler 2001). Dams within native White Sturgeon range include with date of construction in parenthesis; Swan Falls Dam (1901), Upper Salmon Falls (1937), Lower Salmon Falls(1910), Bliss (1950), C.J. Strike dams (1952), the Hells Canyon complex of Brownlee (1959), Oxbow (1961), and Hells Canyon (1967), and four additional dams located in Washington; Lower Granite (1975), Lower Monumental (1969), Little Goose (1970), and Ice Harbor(1961).

Dam construction without fish passage eliminated anadromous salmon, steelhead, and lamprey upstream of the Hells Canyon Complex which provided a historically abundant food supply for White Sturgeon. As anadromous fish runs declined, White Sturgeon were obligated to seek other food sources for survival. While the impact on Snake River White Sturgeon population productivity and condition is unknown, evidence from other Idaho fish species indicates a significant correlation between reduced growth with declines in anadromous fishes.

Declines in White Sturgeon abundance resulted in increased monitoring and management to conserve the species. Overfishing in Idaho was recognized as a causative factor in early sturgeon declines resulting in prohibition of commercial fishing in 1943 and implementation of a yearly 2-fish per angler limit on recreational harvest in 1956, and a statewide catch-and-release regulation on all sturgeon fisheries since 1971 (Cochnauer et al 1985). Increases in White Sturgeon abundance after catch-and-release implementation was documented in some reaches during the 1980s (Lukens 1984, Coon et al. 1977). White Sturgeon population abundance has been stable or increasing in the two Core Wild reaches with natural recruitment since this regulation change, while others have continued to decline. Limiting factors associated with other anthropogenic impacts continue to suppress abundance in other reaches. Continued long-term monitoring of White Sturgeon populations in the 1990s and 2000s involved collaborative efforts between IDFG, the Idaho Power Company (IPC), and Nez Perce Tribe. IDFG sturgeon management objectives became more specifically described in the 1991-1995 Statewide Fisheries Management Plan. Recognizing the importance of this species to Idaho and its anglers, as well as increasing conservation concerns, staff first developed a species-specific management plan for Snake River White Sturgeon in 2008 (IDFG 2008). This document represents an update to the 2008 plan.

CURRENT DISTRIBUTION

White Sturgeon still occupy significant portions of the Snake and Salmon rivers; however, no recent observations of White Sturgeon have been recorded in the Clearwater River. Current population status varies among reaches and depends on a variety of environmental conditions within each reach. We estimate there is currently 812 rkm of occupied habitat in the Snake River drainage above Lower Granite Dam. In addition, starting in the mid-1990s IDFG began stocking White Sturgeon outside their native range on the Snake River upstream of Shoshone Falls. These introductions have been successful and have established popular sturgeon fisheries between Shoshone Falls and the town of Idaho Falls. Thus far there is no evidence to suggest any natural recruitment in the non-native reaches.

CONSERVATION STATUS

Habitat degradation and alteration (and the associated disruption of natural large river processes) and overfishing of White Sturgeon during the past 150 years have resulted in declines in abundance across much of the range. Historically, overfishing of White Sturgeon populations was a significant issue; however, this limiting factor has largely been ameliorated with modern management and focused enforcement efforts. For instance, in the mainstem Columbia River, commercial sturgeon fishing did not begin until 1888 and stocks were considered exhausted within twelve years (Saffron 2004). Since then, increasingly restrictive harvest seasons and limits for commercial and recreational fisheries have allowed sturgeon numbers to increase in the area and once again provide sturgeon harvest in the lower mainstem Columbia River. However, limiting factors such as habitat fragmentation, flow regulation associated with mainstem dams, non-native species, and water quality impairment remain issues across much of the range. Only two of the nine Snake River populations are currently stable or increasing, while the remaining reaches rely on hatchery stocking and downstream drift to maintain their populations.

As a species, White Sturgeon are listed on the United Nations Environmental Programme – World Conservation Monitoring Centre’s Red List of Threatened Animals at the lower risk category; however, some populations are listed as threatened or endangered under the U.S.

Endangered Species Act or the Canadian Species at Risk Act (Auer 2004). In Idaho, White Sturgeon conservation policy is structured into two drainages: the Snake and the Kootenai rivers. Kootenai River White Sturgeon are a Distinct Population Segment Federally Listed as Endangered and managed under a federally mandated Recovery Plan. Snake River populations are designated in the Idaho State Wildlife Action Plan with a NatureServe global rank of G4 (Apparently Secure) and Subnational Rank of S1 (Critically Imperiled). In Idaho, White Sturgeon are considered a Species of Greatest Conservation Need (IDFG 2023). For the Snake River drainage, White Sturgeon remain under state jurisdiction and will be managed using strategies described in the remainder of this document.

LIMITING FACTORS

Dams and reservoirs

Idaho's White Sturgeon populations have decreased for several reasons, but habitat alteration and fragmentation from dams built from 1900 to 1980 are the primary factor. Prior to dam construction, sturgeon migrated across long, connected sections of river habitat, mixing the population and allowing sturgeon to access habitats needed to complete their life cycle. Dams and reservoirs result in a suite of environmental or physical conditions that alter habitat for Snake River White Sturgeon. Dam construction and the associated changes to river habitat have blocked migrations and altered flows, water temperatures, and nutrient regimes. A once continuously connected river corridor has been segmented into fragmented river reaches, isolating populations among shortened river reaches and reservoirs. In many instances, environmental conditions which remain in these reaches do not support natural recruitment of White Sturgeon.

Alterations in the annual, seasonal, and daily flow regimes for water management and hydropower have reduced peak flows, shifted timing and volume of peak flows which affect water quality, nutrient and substrate transport and fish communities. Dam construction and subsequent reservoir formation, and development across the Snake River plain has altered water quality, most notably including dissolved oxygen and temperature. In some instances water quality is less than optimum or seasonally unsuitable for White Sturgeon survival. Dams on the Snake River and tributaries altered nutrient transport and substrate movement that historically occurred. In the Snake River above Hells Canyon, dams eliminated anadromous salmon, steelhead, and lamprey, which were an abundant food source for sturgeon. Dams have also changed the composition and abundance of previously abundant prey items. Finally, reservoirs have altered the former river corridor into a series of slack water environments with associated changes in fish species composition and abundance. This may have increased predation by and competition with other species.

Direct mortality associated with dam infrastructure operations has been documented in multiple Snake River reaches. White Sturgeon entrainment occurs through dam turbines and spill gates typically during periods of high flow (IPC 2015). IDFG and IPC field sampling has documented downstream movement and survival of adult sturgeon past Snake River dams between Idaho Falls and Lower Granite Dam. Downstream movement over spill gates allows a relatively high probability of survival. Downstream movement through turbines turbine infrastructure results in lower survival due to potential turbine blade strikes and barotrauma (IPC 2015). The installation of turbine intake grates on the upstream side of the dam has reduced mortality by preventing large White Sturgeon from entering turbine intakes (Jager 2001). White Sturgeon have been known to swim up turbine outlet infrastructure from the downstream side of the dam and may be killed by blade strike when turbines restart. IPC has implemented turbine-strike prevention stipulations to reduce direct mortality; however, continued monitoring is warranted to limit effects on larger sturgeon within these reaches.

Connectivity

White Sturgeon life history becomes a limitation when populations are confined to relatively short river reaches that lack the required habitats for all life stages. Under current conditions in the Snake River, many of the short river reaches show little or no evidence of natural recruitment. The absence of recruitment stems from: 1) lack of suitable spawning habitat in the reach; and 2) reduced reach length whereby fish are vulnerable to downstream losses (past dams) that reduce production potential (IPC 2005). Sturgeon are susceptible to entrainment throughout their life cycle, from free-drifting larvae immediately post-hatch through adulthood where entrainment has been documented via spillway gates (IPC 2015). The absence of recruitment jeopardizes the long-term persistence of some populations. In short reaches, post-spawn females have been collected during monitoring, indicating that spawning occurred but without subsequent recruitment of juveniles. Larval drift in these short reaches likely results in entrainment downstream, and poor water quality conditions in summer may result in complete mortality shortly after spawning.

Fragmentation shortens reach lengths and result in lower natural recruitment, unbalanced size structures and contributes to low genetic diversity among reaches. Only longer reaches of the Snake River with free-flowing river habitat (>50 km; Lower Granite Dam to Hells Canyon and C.J. Strike to Bliss Dam) support natural recruitment of White Sturgeon. The one exception to longer reach length supporting natural recruitment is the Swan Falls to Brownlee reach which is the longest segment of free-flowing river (190 km) but does not support any detectable level of natural recruitment (Bentz and Hughes 2020a). The lack of natural recruitment in this reach is thought to be caused by water quality impairment and channel morphology (IPC 2005). Fragmentation of the river corridor has implications for long-term genetic structuring of White Sturgeon in the Snake River. Although genetic monitoring has documented partitioning of the species on broad scales (e.g., differentiation between the Snake River and lower Columbia River), smaller scale mixing of populations in the Snake River occurred in the past. The loss of connectivity associated with dam construction has not led to genetic concerns yet, given that individuals in contemporary populations were still alive when connectivity was present. Management actions to promote connectivity between reaches have already occurred in some reaches and will be considered in all reaches through translocation and hatchery stocking when appropriate.

Improving connectivity for White Sturgeon across multiple Snake River reaches would increase population resiliency; current dam infrastructure precludes sturgeon from upstream passage on their own. White Sturgeon do not readily use conventional fish ladders therefore active translocation is the most cost effective and feasible method for addressing upstream movement at this time. Limited downstream passage of White Sturgeon within the Snake River has been documented; however, no subsequent upstream migration has been documented in reaches with fish ladders designed for salmon and steelhead passage (PTAGIS query). The inability of White Sturgeon to move freely past dams on the Snake River has resulted in low overall population abundance, lost juvenile and adult production due to downstream entrainment, or decreased survival for larvae that drift into reservoirs or other sub-optimal habitats. To mitigate for the impacts of reductions in sturgeon survival and abundances the Snake River White

Sturgeon hatchery program is used to maintain abundance in reaches that lack the habitat diversity to support all life histories and expand sport-fishing opportunities.

Flow regulation

The Snake River is extensively regulated to provide water for agriculture, hydropower, municipalities, and to reduce the risk of flooding. This has resulted in alterations in the natural hydrograph and significant reductions in the natural flow of the Snake River. A large-river obligate species such as White Sturgeon has adapted to dynamic river conditions to complete its life cycle.

Substantial alteration of flows or temperature prior to or during White Sturgeon spawning can interfere with the necessary environmental cues that provide suitable spawning or rearing conditions. Historically, sturgeon recruitment in the Snake River was variable but more regular recruitment events occurred even at lower flow conditions than currently observed (Lepla 1994). Recruitment of juvenile White Sturgeon has been documented to be positively related to the volume of river flow during spring (Parsley and Beckman 1994; Miller and Beckman 1996; Brink and Chandler 2000; Chandler and Lepla 1997). IPC's juvenile White Sturgeon Index surveys in the mid-Snake River and Hells Canyon have documented highest recruitment events correlated with highest spring river flows and limited reproduction in years of low flows during spring in the mid-Snake River (Hughes 2020). Water temperatures and fluctuations in water temperature have also been shown to affect White Sturgeon spawning behavior and success (Paragamian and Wakkinen 2002). Because the diet of White Sturgeon is composed primarily on crayfish, snails, invertebrates, and fish (alive or dead), flow reductions at any time of year that negatively affect the abundance of other aquatic organisms will concurrently have a negative influence on sturgeon via reduced food resources.

Flow fluctuations such as daily power peaking at hydropower facilities for power generation can affect recruitment potential for White Sturgeon (IPC 2005). Instream flow studies conducted by IPC below Lower Salmon Falls, Bliss, C.J. Strike, and Hells Canyon dams have illustrated that load following or power peaking operations can substantially reduce the amount of spawning, incubation, and larval habitats for White Sturgeon, particularly during low water years (IPC 2005). For example, the estimated age structure of White Sturgeon sampled in 2000 below Bliss Dam indicated that natural recruitment of White Sturgeon was poor during below normal water years when high load following operations occurred (1988, 1989, and 1990; Brink and Chandler 2000). In years with similar hydrology but limited or no load following (1992, 1993, and 1994), higher recruitment of White Sturgeon occurred.

Water quality

Water quality throughout the Snake River has been affected by intensive agriculture as well as industrial and municipal activities (Clark 1998: Harrison et al. 1999). Much of the mainstem Snake River is listed as impaired or water quality-limited (Idaho Department of Environmental Quality 2022). Water quality factors affecting sturgeon survival include high water temperature, low dissolved oxygen, high nutrient and contaminants, and high dissolved gases. Water quality generally becomes more impaired during low flow periods from mid- to late summer. During the summer irrigation season when water demand is high, reduced river flows and irrigation return flows combine to impair water quality. Irrigation return flows to the Snake River are significant contributors of nitrogen, phosphorus, pesticides, and sediment (Clark 1998).

Summer water temperatures in the Snake River often exceed optimal levels for sturgeon. Water temperature recorded at U.S. Geological Survey river gauges on mid-Snake River reaches routinely exceed 28˚C in mid-summer. While lethal thermal tolerances for White Sturgeon have not been published, the Snake River is subject to summer water temperatures that can inhibit growth and reduce sturgeon survival. The effects of water temperature are likely life stage dependent. Wang et al. (1985) documented larval White Sturgeon mortality at temperatures greater than 20°C. Temperatures exceeding 23°C were documented to reduce juvenile White Sturgeon growth and feeding rate (Hung et al. 1993). A study assessing maximum growth and food consumption in juvenile Atlantic Sturgeon observed optimal conditions at 20°C. (Niklitschek and Secor 2009). High summer water temperatures also lead to reductions in dissolved oxygen.

Mortalities of White Sturgeon directly attributable to impaired water quality have been documented in the Snake River in the Swan Falls Dam to Brownlee Dam reach (Grunder et al. 1993). Jager et al. (2001) found poor water quality was a dominant factor in limiting recruitment of White Sturgeon in most reaches in the Snake River. Poor water quality can affect multiple life stages of White Sturgeon and are most problematic when sturgeon are unable to move to better water quality environments in reservoir habitat (Sullivan et al. 2003). Water quality effects on sturgeon survival in the Snake River warrant continued monitoring and additional research as a number of publications have documented negative sublethal and lethal effects of high water temperature and low dissolved oxygen on other sturgeon species (Secor and Niklitschek 2001, Niklitschek and Secor 2009, Crocker and Cech 1997).

Nutrient loading associated with municipal, industrial and agricultural discharge impair water quality, specifically dissolved oxygen. Excessive nutrient inputs such as nitrogen and phosphorus promote algal growth which create oxygen during photosynthesis but use oxygen during respiration (IPC 2018). These conditions coupled with high summer water temperatures often reduce dissolved oxygen concentrations and create anoxic zones in mid-Snake River reservoirs.

Supersaturation of total dissolved gas (TDG), associated with spill operation at hydropower facilities, has been documented to negatively affect a variety of fish species and some sturgeon life stages. While adult sturgeon are less susceptible given that they are bottom-oriented, larval life stages which drift in the water column can be affected. Larval sturgeon exposed to 131% TDG for 13 hours suffered 50% mortality in a laboratory study (Counihan et al. 1998). Sublethal effects such as gas bubbles in the buccal cavity and nares manifested themselves at lower TDG levels and under shorter durations (Counihan et al. 1998). TDG levels associated with Snake River hydropower facilities such as Oxbow, Brownlee, and Hells Canyon dams have been documented to range between 110-136% (IPC 2018). TDG levels in excess of 110% persisted below Hells Canyon Dam to the mouth of the Salmon River during spill periods of 20,000 cfs or higher (IPC 2018). Additional monitoring of TDG levels and potential impacts on sturgeon recruitment will refine the potential effects on Snake River populations.

Long-lived fishes such as White Sturgeon are known to bio-accumulate contaminants such as heavy metals. While the exact mechanism that affects fishes is unclear, there is evidence across numerous studies documenting negative effects on reproduction associated with mercury (Crump and Trudeau 2009). One such study involved Columbia River White Sturgeon which documented potential negative reproductive effects (Webb et al. 2006). Samples collected by IDFG, IPC and the USGS have documented mercury concentrations throughout Snake River reaches. In general, environmental mercury was present across all fish sampled with highest concentrations present in the largest individuals. Concentrations of methylmercury in sturgeon sampled in Hells Canyon in 2014 all exceeded Oregon guidelines (Bentz 2015a). High levels of mercury have also been observed in sturgeon mortalities between C.J. Strike and Swan Falls dams, though a variety of factors likely caused or contributed to these mortalities (IPC 2013). Lead levels were also sampled in Hells Canyon in 2014 with 48% of sturgeon sampled having concentrations below detectable levels (Bentz 2015a). Outside of the Snake River, increasing levels of Selenium have been documented in Kootenai River White Sturgeon resulting in greater concern given sturgeon are highly sensitive to this contaminant (G. Hoyle, Kootenai Tribe, personal communication). The extent of population level impact of containments on White Sturgeon is unknown, but continued contaminant monitoring of should be conducted to maintain baseline data and inform future management decisions based on monitoring and research findings.

Altered fish assemblage

The introduction and spread of non-native aquatic species into the Snake River may be causing adverse competitive interactions and predation on White Sturgeon populations. Atlhough interactions between sturgeon and the suite of other fish species within the Snake River have been relatively understudied and warrant continued management consideration. A variety of fish species have been documented to consume White Sturgeon eggs and young-of-the-year (Miller and Beckman 1996), including non-native fish species such as Channel Catfish *Ictalurus punctatus* and Walleye *Sander vitreus,* which feed on juvenile White Sturgeon of various size classes (Gadomski and Parsley 2005). Northern Pikeminnow *Ptychoocheilus oregonensis*, a native species, also prey upon juvenile sturgeon (Gadomski and Parsley, 2005). It is unknown if predation rates by non-native fish species are additive or compensatory to historical predation. Regardless, IDFG will carefully consider any potential negative affects prior to any non-native species introductions into Idaho's sturgeon habitats.

Recruitment failure

Only two reaches currently sustain viable naturally reproduction of White Sturgeon in Idaho. These reaches are Bliss Dam to C.J. Strike Reservoir and Hells Canyon Dam to Lower Granite Reservoir. Under current conditions in the Snake River, many of the short river reaches show little or no evidence of natural sturgeon spawning. The absence of spawning stems from: 1) a lack of suitable spawning habitat in the reach, 2) reduced reach length whereby populations lack access to habitats required for all life stages or are vulnerable to downstream losses (past dams) that reduce production potential, and 3) spawning triggers (e.g., flow and environmental cues) are not met within the reach (IPC 2005). Sturgeon are susceptible to entrainment throughout their life cycle, from free-drifting larvae immediately post-hatch through adulthood where entrainment has been documented via spillway gates (IPC 2015). Post-spawn, recruitment can be limited by water quality issues including temperature, dissolved oxygen and contaminant related limitations. The absence of recruitment requires significant management actions to ensure long-term persistence in these reaches. At best, small populations within short river reaches and limited recruitment are vulnerable to stochastic and catastrophic events. Jager et al. (2001) demonstrated via simulation models that increased habitat fragmentation led to an exponential decline in the likelihood of persistence of White Sturgeon populations. Thus, it is challenging to conserve and manage wild sturgeon populations in the reaches of the Snake River that lack sufficient length of free-flowing river between dams.

Climate change

Terrestrial and aquatic ecosystems across the Pacific Northwest are changing due to climate change. In general, air temperature is predicted to increase 3-6˚C depending on fossil fuel emission scenario and geographic location (Abatzoglou et al. 2021). Summer and winter air temperatures are predicted to increase at a greater level compared to other seasons (Abatzoglou et al. 2014). Precipitation levels are predicted to remain variable; however, precipitation is predicted to become more rain driven compared to snow with runoff occurring earlier in the season (Abatzoglou et al. 2014). Across the Columbia River basin, long-term (50-75 years) water temperatures have been rising at 0.03˚C per year (O'Connor 2021). The effects of climate change are expected to alter temperature and precipitation, which could also lead to further changes to ecological interactions (Caudill et al. 2021). The level of future effect on White Sturgeon in the Snake River will depend on a variety of factors within this regulated river system.

Summer water temperatures within the Snake River have increased during the past 50 years and are projected to continue to increase in the future. Modeling conducted by the Idaho Power Company predicts warmer than baseline Snake River water temperature in all seasons and locations of the Snake River from Milner Dam to Brownlee Dam (IPC 2020). However, certain seasons and areas appear more susceptible to warming water temperatures. Late summer and early fall water temperature and seasonality of runoff associated with White Sturgeon spawning are of specific concern. Warmwater temperatures in reservoir habitat have also resulted in portions of the water column turning anoxic in some mid-Snake River reservoirs (IPC 2018) and have exacerbated other water quality problems (such as harmful algal blooms). The duration and spatial extent of anoxic conditions could increase as water temperature and flow conditions continue to be affected by climate change.

Climate change related alterations in streamflow timing and volume are expected to affect Snake River White Sturgeon. Predicted streamflow for the Snake River near Weiser is expected to decline and peak earlier in the next 50 years (Kliskey et al. 2019). Alterations in volume and timing of streamflow in Idaho rivers are expected as precipitation in winter shifts from snow to rain in many drainages (Humes et al. 2021). These alterations have the potential to affect White Sturgeon natural recruitment which requires a specific combination of flow and temperature to trigger spawning. Water management of the mainstem Snake River significantly influences water temperature and flow timing even in the absence of climate change scenarios. However, water management infrastructure may also provide some mechanisms for mitigating climate change effects. IDFG will work with partners to prioritize strategies and manage water resources to reduce the effects of climate change on White Sturgeon populations based on the best available science and management tools.

Recreational angling

White Sturgeon populations require high annual survival to maintain abundance and size structure. Regulations that eliminated harvest fisheries and adoption of statewide catch-and-release fishing regulations benefited Idaho's sturgeon populations. Research in the early 1970s and 1980s documented improved recruitment and lower annual mortality of White Sturgeon in a matter of ten years (Coon et al. 1977, Lukens 1984). Recent assessments documented continued increases in the number of mid- to large-size individuals within the two naturally recruiting reaches (Hells Canyon and the Bliss reach; Bentz 2015a; Bentz and Hughes 2022). Current estimates of total annual survival for White Sturgeon reaches range from 75 to 96% for all life stages and 92 to 98% for adults (Appendix A). Survival rates in some reaches indicate catch and release is compatible with management objectives, in other reaches survival rates are lower and even slight increases in angling related mortality may result in long-term decreases in reach abundance or size structure. Reaches which exhibit lower survival are generally subject to decreased water quality conditions and shorter lengths than reaches with higher survival. Understanding what role angling plays in population size structure and abundance in these reaches relative to other sources of mortality is important to ensure adequate seasons and rules are implemented.

Catch and release angling for White Sturgeon is a popular activity in the Snake River. Angling efforts can be high on some spatial scales (e.g. tailraces) in some reaches. In areas with high angling effort, White Sturgeon may be caught several times per year. Kozfkay and Dillon (2010) estimated that White Sturgeon in the C.J. Strike tailrace – a section with high angling effort – were caught an average of 7.7 times per year. Such repeated landings are common in popular catch-and-release fisheries for trout and bass (e.g., Schill et al. 1986; Burkett et al. 1986; Hayes et al. 1997). While catch and release mortality from angling has been low, monitoring angler effort on sturgeon fisheries, especially in high use reaches, remains an important management objective.

The upper thermal tolerance for White Sturgeon has not been clearly identified, however, higher water temperatures and low dissolved oxygen are a common risk factor in catch-and-release fisheries. Stress-related effects associated with angling activity under these reduced water quality conditions may affect sturgeon growth and survival. While McClean et al. (2020) found 100% survival of angled White Sturgeon in the Fraser River (n = 121), the results indicated greater stress at higher water temperatures and longer fight times. Poor water quality occurs in many reaches of the Snake River and warrants continued evaluation of the effects of angling during periods of low dissolved oxygen and high temperatures.

Occasionally, dead sturgeon are found in the Snake River, often with substantial amounts of terminal tackle (hooks, line, and swivels) in their digestive tracts. IDFG collaborated with IPC to conduct a series of studies to addressing the following questions: 1) how often were White Sturgeon deep-hooked by anglers, 2) could deep-hooking be reduced by using hooks designed to minimize deep hooking, such as circle hooks, 3) what proportion of White Sturgeon had ingested metal or other angling terminal tackle in their digestive system, and what impacts did such ingestion have on sturgeon populations, and 4) can White Sturgeon pass tackle such as hooks and swivels through their digestive system, and if so, how long does such passage take?

Lamansky et al. (2017) evaluated hooking and landing success for anglers bait fishing for White Sturgeon comparing circle- and J-hooks fished with the traditional “active” hook set (i.e., set the hook when a strike is detected) and a “passive” hook-set (i.e., reeling without setting the hook, as circle hook manufacturers recommend). After landing over 500 sturgeon from 60 to 316 cm (mean = 137 cm), the study documented extremely low (<1.0%) deep hooking rates and high landing rates with all hook types and angling methods. The deep-hooking rate was so low, the authors concluded that ingested tackle in sturgeon was likely from sturgeon consuming hooks still attached to bait on the bottom of the river left behind by anglers who snagged and broke their line.

The presence of hooks or other angling tackle in White Sturgeon populations was assessed with field studies and lab simulation. Studies documented metal ingestion in a high proportion of White Sturgeon, especially larger size classes (Bowersox et al. 2016; Lamansky et al. 2018a) and confirmed that ingested tackle included swivels and gear from other species such as bass and steelhead (Figure 1). White Sturgeon with metal in their digestive systems, on average, weigh slightly (but statistically significantly) less than fish without metal (Figure 2). Based on multiple fish recaptures during the studies, it was documented that hooks corroded through time and were passed by White Sturgeon (Figure 3). The corrosion of sturgeon-sized angling hooks was evaluated in a laboratory study (Lamansky et al. 2018b), demonstrating that regardless of the hook condition (brand new or scratched and abraded), hook strength was reduced to breaking within one year of constant exposure to stomach-like acidic conditions.

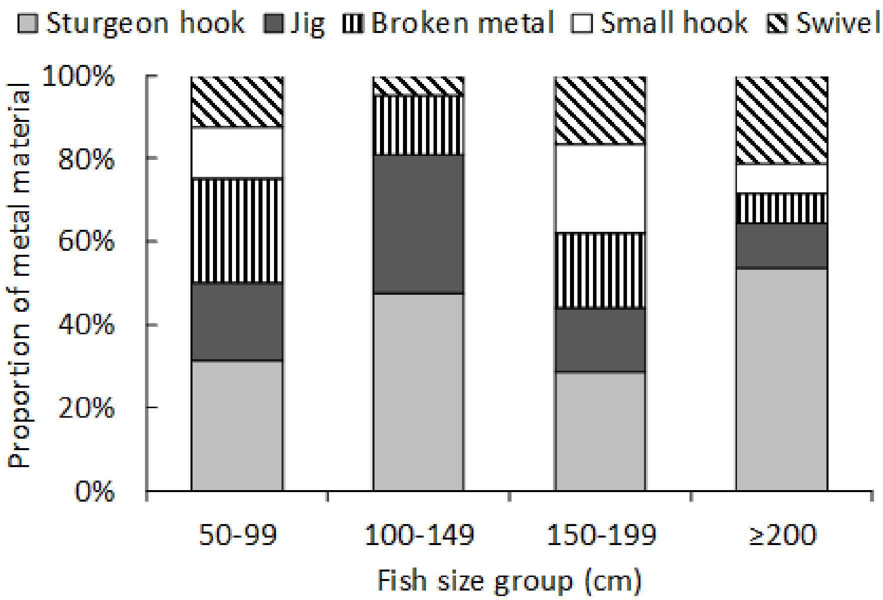

Figure 1. Types of metal observed in the digestive tracts of x-rayed White Sturgeon captured in the Hells Canyon reach of the Snake River, Idaho, by size group.

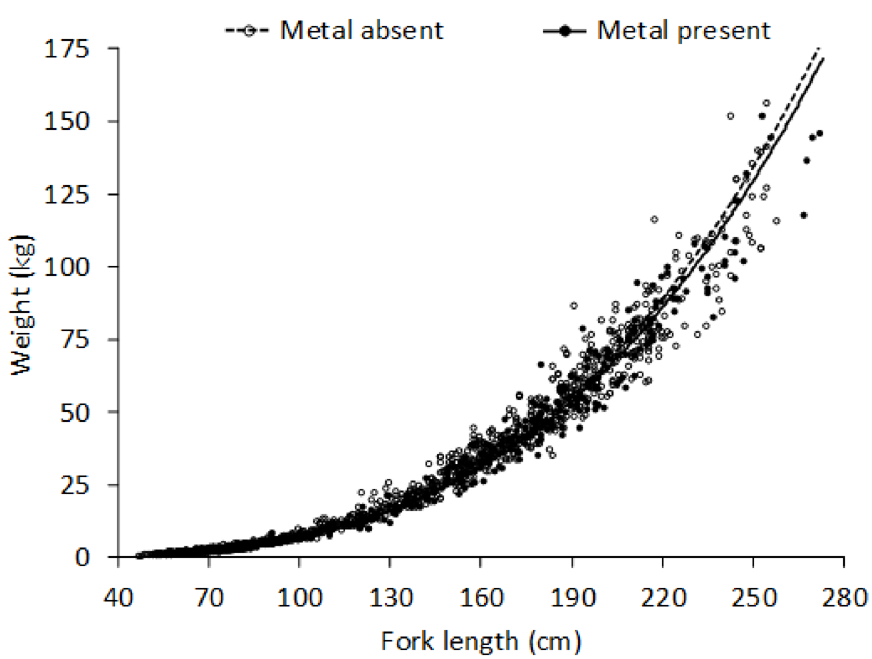

Figure 2. Comparisons of fork length to weight of White Sturgeon that contained metal (solid circles, solid line) and those that did not (open circles, dashed line) sampled from

the Hells Canyon reach of the Snake River, Idaho. Lines fitted to the data are power functions.

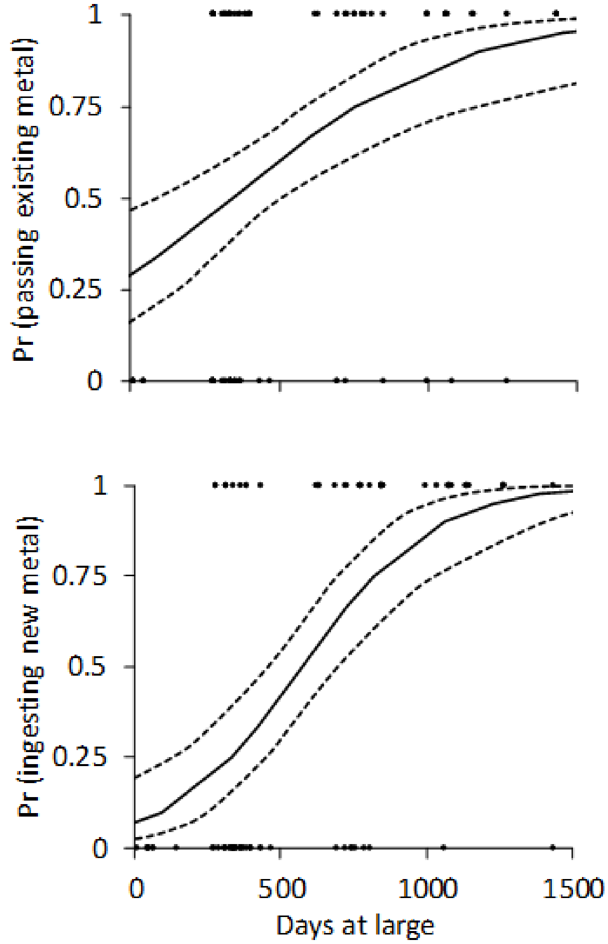

Figure 3. Logistic regression relationships between days at large (i.e., time between x-rays) and the likelihood of either shedding existing metal or ingesting new metal for White Sturgeon in the Hells Canyon reach of the Snake River, Idaho. Dotted outer lines are 95% confidence intervals for the relationship.

MANAGEMENT STRATEGIES

Population monitoring

Reach abundance, trends, and size structure will be the primary tool for assessing sturgeon reaches and implementing management. Intensive assessments of White Sturgeon abundance, size structure, and recruitment will continue in the Snake River. Idaho Power Company, as conditions of federal licenses for their hydropower facilities, will conduct these scheduled assessments in consultation or cooperation with IDFG. Idaho Power Company has outlined a plan to conduct population assessments in the middle Snake River upstream of Brownlee Dam to Shoshone Falls every 5 years, and reaches downstream of Brownlee Dam to Lower Granite Dam every 10 years (IPC 2015). Sampling in addition to standard population status monitoring by IDFG and IPC will occur as needed.

Standardized sampling methods are important so that descriptions of abundance and size structure can be compared across time or among reaches. Within a reach, detecting changes in abundance or size structure will require consistent standardized monitoring. Any detected changes in recruitment, growth, or survival would require further investigation to determine the cause. Fork length will be monitored in all population assessments to characterize sturgeon abundance by life stage with the following length criteria: juveniles (<95 cm), sub-adult (95-162 cm), and adults (>162 cm).

Natural recruitment emphasis

Emphasizing natural recruitment will remain the top priority to support White Sturgeon populations within Idaho. Management strategies to promote natural recruitment and provide adequate habitat for sturgeon to complete the full life cycle will remain the foremost priority, in all reaches within the historical distribution of White Sturgeon in Idaho, including those currently supported by hatchery stocking. In addition, as management strategies are implemented which promote better natural spawning conditions, stocked sturgeon are expected to spawn successfully after reaching maturity, leading to further increases in abundances.

Hatchery stocking strategies

Hatchery stocking will not be used in Core Wild reaches specifically Hells Canyon and C.J. Strike to Bliss reaches. However, most reaches of the Snake River no longer support natural reproduction, and these populations may require varying levels of hatchery stocking to reach population abundance objectives. IDFG supports stocking using the best available conservation aquaculture techniques when required to achieve population abundance and recreational fishing objectives in those reaches identified in this plan.

Previous White Sturgeon stocking efforts in the Snake River drainage presented genetic and conservation concerns. Original stocking efforts were based on outplanting broodstock and progeny from local commercial aquaculture facilities whose fish were originally sourced from the Snake River White Sturgeon populations. This approach was discontinued due to genetic concerns and the following program used progeny from wild broodstock collected in the Bliss to C.J. Strike, subsequently spawned in captivity and juveniles were then reared and released. Fish were raised at the College of Southern Idaho Fish Hatchery and released into mid-Snake and upper Snake River reaches. Post-spawn wild broodstock were subsequently returned to the Bliss

Reach after recovering. While using F1 offspring from wild parents reduce concerns over genetic origin, captive spawning of wild adults presented challenges. The number of families (and genetic diversity) represented in each year class was limited by the number of adults captured for spawning, even using full factorial matings. Captive spawning risked stocking many individuals that represented only a few families with much lower genetic diversity over the long-term given the longevity of the species (Schreier et al. 2013). Captive spawning also increased the frequency of unusual offspring of abnormal ploidy, which needed to be culled from the release groups.

The current program using repatriation of wild-spawned eggs and larvae was developed to address genetic concerns associated with potential inbreeding depression and genetic simplification of supplemented reaches (IPC 2021). Repatriation aquaculture is a process by which wild-caught White Sturgeon (egg or larvae) are brought into the hatchery and reared to release at a larger size (juvenile) back into the wild (IPC 2021) This practice increases juvenile sturgeon abundance in the wild by increasing survival rates from egg to juvenile life stages by protecting them in a hatchery setting, and then re-releasing them after they have reached a critical minimum size. This method is preferable to traditional broodstock-based aquaculture, as many families are represented, and wild genetic structure is better represented (IPC 2021).

IDFG supports the continued use of the C.J. Strike Dam to Bliss Dam reach as the source population for the repatriation hatchery program. The White Sturgeon population in this reach contains high levels of genetic diversity and is genetically similar to other reaches between Shoshone Falls and Brownlee Dam. These properties make is the sensible choice for collecting eggs/larvae for stocking into isolated reaches. From 2015 to 2021, the program has collected nearly 83,000 eggs resulting in 6,170 juvenile sturgeon stocked back into the wild (Table 1). In addition, the program has demonstrated retention of genetic diversity represented within the wild source population (IPC 2020). IDFG supports the continued implementation of the repatriation program for future White Sturgeon stocking in the Snake River when deemed necessary to meet management objectives.

Table 1. Wild eggs and larval White Sturgeon collected by Idaho Power Company (courtesy of Idaho Power Company).

Year Class	Eggs and Larvae Collected	Juvenile Production
2014[1]	241	NA
2015[1]	1,165	NA
2016	770	37
2017	445	92
2018	1,756	238
2019	28,139	2,174
2020	26,984	1,978
2021	23,420	1,651[2]
Total	82,920	6,170

[1]Collection archived for genetic diversity analysis
[2]Estimated numbers at time of reporting

Continued implementation of the White Sturgeon stocking program will be conducted at the IPC Niagara Springs Sturgeon Hatchery which was completed in 2021. The hatchery isa cooperative effort funded by IPC and operated by IDFG staff. IPC staff are responsible for collecting wild eggs/larvae and work in close cooperation with Niagara Springs hatchery staff during the rearing, marking, and stocking process. Goals of the hatchery program are outlined in the IPC Conservation Hatchery Management Plan (2021), and the oversight and management for stocking is coordinated with IDFG.

The need and methodology for monitoring the influence of conservation aquaculture on genetic diversity to recipient reaches within the Snake River is described in Schreier et al. (2013), and in Schreier et al. (2020). We anticipate repatriation stocking will eventually homogenize the genetic diversity of White Sturgeon populations among Snake River reaches. However, maintaining overall genetic diversity will remain a higher priority than preserving reach-specific differences (Schreier et al. 2020).

Managing abnormal ploidy in hatchery White Sturgeon stocking continues to be of high importance to IDFG and is achievable within the repatriation program. Abnormal ploidy occurs when an individual contains extra chromosomes compared to a ‘normal’ individual. In the case of sturgeon an abnormal ploidy individual is 12N versus a ‘normal’ 8N. The resulting spawn crosses between 8N and 12N individuals result in 10N offspring. Both 12N and 10N individuals can express a variety of reproductive impairments that have potential negative effects on overall population abundance (Comai 2005). All individuals released as part of the repatriation program will be screened for abnormal ploidy prior to release and culled upon detection. To date, abnormal ploidy levels in the program have been less than 1.5% (IPC 2021). Monitoring for abnormal ploidy became common during the last years of captive spawning, but some White Sturgeon stockings prior to the repatriation program monitoring may include some abnormal ploidy individuals. Any sturgeon sampled in the field with documented abnormal ploidy will be culled from Idaho waters.

Fish marking

Marking strategies have been developed to identify wild and hatchery-origin White Sturgeon in the middle Snake River. Removing White Sturgeon lateral scutes is a common and effective method for differentially marking groups of fish. All stocked sturgeon in Idaho waters from captive broodstock origin will be marked by removing the second right lateral scute. All sturgeon from repatriation aquaculture will be marked by removing the 5th right lateral scute. Naturally produced wild-origin sturgeon sampled during surveys in Idaho waters will have their second left lateral scute removed. In addition to scute marking, all White Sturgeon stocked in Idaho waters and unmarked sturgeon encountered during surveys will be PIT-tagged to help track movement, growth, and survival and to help evaluate stocking efforts.

Genetic monitoring and management

One of the core principles of fisheries conservation is that genetic diversity of populations should be maintained. Genetically diverse populations are much more resilient to stochastic changes are less likely to be extirpated, and typically have higher reproductive success (Reed 2003). A recommended framework for monitoring genetic diversity in White Sturgeon in the Snake River (native populations) was developed for IPC by Schreier et al. (2013). This genetic monitoring plan recommends a rotation of sampling with supplementation or translocation on a 5-year interval, and a 10-year interval for reaches without supplementation.

Baseline data describing genetic variation across White Sturgeon in the Snake River is described by Schreier et al. (2013). The authors showed genetic diversity differed noticeably between sturgeon from the Lower Snake River (Hells Canyon to Lower Granite Dam) and those from Middle Snake reaches (Shoshone Falls to Brownlee Reservoir). Results identified the Lower Snake and Middle Snake reaches as distinct populations, with the Lower Snake section showing evidence of an admixture of influence from the Middle Snake, as well as another population, likely from historical mixing with the Lower Columbia and Snake river reaches downstream. The apparent differentiation of these two major population groups suggests significant natural isolation to gene flow even before impoundments were in place.

The primary strategy for conserving native White Sturgeon genetic diversity in the Snake River will be to focus protection and conservation efforts of the Hells Canyon and Bliss reach populations. Protecting these two reaches will have the combined benefit of maintaining the genetic diversity unique to each of these different populations (Schreier et al. 2013), and protect large, diverse populations that can be used to assist in managing nearby isolated populations with no natural recruitment.

Since effective population size cannot be measured with currently available techniques, estimating the number of annual spawners is a more appropriate measure to examine genetic diversity in these populations (Schreier 2013). To measure genetic diversity, the number of alleles per individual across 13 loci will be used as a surrogate for diversity. This is because the duplicated genome in White Sturgeon prevents measuring heterozygosity directly. Monitoring changes in genetic diversity over time will be needed to evaluate the impact of management actions and decide when changes are needed to preserve diversity and prevent further losses. If natural recruitment continues in both these reaches, active management to maintain genetic diversity will not be necessary, though translocation of downstream entrained fish back into these reaches is recommended as a management tool. The second strategy for maintaining genetic diversity in the isolated reaches of the Middle Snake River will require translocation or conservation aquaculture, described elsewhere in this plan.

Translocation

Translocating natural-origin or stocked White Sturgeon may be used to help maintain connectivity and promote gene flow between reaches and supplement the number of spawning adults in reaches that still support natural reproduction. Translocation may be as a management strategy when: 1) moving natural-origin mature adults into reaches that support natural reproduction is desirable to increase gene flow among isolated reaches, 2) translocating fish which were entrained into downstream reaches 3) translocating fish from reaches exceeding abundance objectives into reaches not meeting abundance objectives, 4) moving fish within reaches to more productive habitats to accelerate growth and sexual maturation rates or 5) White Sturgeon salvaged from canals will be relocated to upstream reaches.

Commercial aquaculture

The IDFG will continue to support the commercial aquaculture industry in their effort to raise sturgeon using methods consistent with conservation and management goals. IDFG supports continued transfer of excess sturgeon eggs from the College of Southern Idaho aquaculture or the IPC repatriation program to commercial hatchery facilities to reduce the genetic differences between commercially reared and natural populations in the Snake River. The IDFG will work with private commercial aquaculture facilities to maintain native stocks of F1 generation progeny in facilities to reduce genetic concerns associated with accidental release and prevent importation of non-native sturgeon stocks. Negative effects associated with non-native sturgeon introductions on native stocks can range from genetic introgression between hatchery and wild stock to hybridization across species (White et al. 2023). The C.J. Strike Dam to Bliss Dam reach will be used to collect F1 progeny for this process when needed. Requests for sturgeon stocking by private parties will be reviewed by Regional Fish Managers to ensure stipulations outlined in this plan regarding non-native sturgeon or non-native White Sturgeon genetic stipulations outlined within this plan are met.

Recreational angling

IDFG will continue to manage fisheries and provide angling opportunity for Snake River White Sturgeon where angling is consistent with conservation objectives. Current sturgeon fishing rules have shown compatibility with conservation objectives. Gear and fish handling rules are intended to reduce “ghost” gear on the river bottom, minimize injury to the fish, and maintain low rates of fishing mortality. These rules include:

1. Sturgeon limit is 0, catch-and-release
2. Sturgeon must not be removed from the water and must be released upon landing
3. Barbless hooks are required
4. Use of a sliding swivel device to secure a weight, and a lighter test line to secure weight to sliding swivel device are required

IDFG will carefully monitor these fisheries to ensure that total mortality rates do not increase. Even minor increases in mortality can reduce population abundance, age structure, or average size in long-lived fishes such as sturgeon. Under certain conditions, sturgeon may become highly vulnerable to angling, and management agencies must be able to quickly respond to avoid overfishing (Hildebrand et al. 2016; Scarnecchia and Schooley 2022). If warranted, the IDFG will propose additional gear restrictions or changes to fishing seasons to reduce angling-related mortality.

Catch-and-release fisheries

Recent research and long-term growth of sturgeon populations in Core Wild reaches suggests that catch-and-release angling can be compatible with long-term sturgeon conservation. While catch-and-release angling may cause low level of mortality, recreational angling opportunity is compatible with achieving populations objectives. Fisheries managers will continue to monitor and consider factors that could potentially increase the effect of catch-and-release angling.

Priorities for continued research into recreational angling effects on White Sturgeon include: 1) develop a better understanding of the level of angling effort in Snake River reaches, particularly in high intensity tailwater fisheries 2) assess the influence of repetitive catch-and-release captures on sturgeon mortality and recruitment, 3) evaluate whether catch-and-release fishing mortality rates are unacceptable during periods of poo water quality (e.g. temperature and dissolved oxygen). 4) potential consequences of catch-and-release sportfishing on spawning success or post-spawn mortality.

Harvest fisheries

Because of the altered habitat and low population productivity in the Snake River it is unlikely that any sustainable harvest opportunity on wild fish will be provided during the duration of this plan. However, harvest in non-native and hatchery-supported reaches may be a viable option in some cases. Beginning in 2014, hatchery sturgeon have been more consistently stocked into several reaches of the Snake River including several reaches outside of the native range upstream of Shoshone Falls. Adequate survival and growth rates have led to increases in abundance and size structure, allowing for angling opportunities. Hatchery-supported sturgeon fisheries have been managed exclusively with catch-and-release regulations; however, some anglers have expressed a desire to harvest sturgeon. Catch-and-release fishing is popular, and harvest may impact catch rates or size structure of White Sturgeon in these reaches resulting in reduced satisfaction for catch-and-release anglers.

IDFG may consider developing sturgeon harvest seasons after taking into account biological, health-related, and social information. Additional information such as reach-specific information on survival and growth, determination of sustainable harvest yields, consideration of heavy metal or other environmental contaminants in fish, as well as public opinion as to preferences on reach objectives (e.g. harvest versus catch-and-release) and preferred methods of structuring fisheries and allocating limited harvest.

Angler education and compliance

IDFG will continue to develop and distribute information on White Sturgeon status and fishing opportunity in Idaho and will promote angling and fish handling techniques that minimize fishing-related mortality. Sturgeon angling tips, recommended terminal tackle, and proper handling methods are provided in the fishing proclamation booklet and administrative rule. IDFG will also produce public outreach videos on White Sturgeon biology, status, and fishing techniques and update the existing sturgeon fishing best practices pamphlet for public distribution.

Highest priority for enforcement efforts will be on reaches designated as Core Wild. Other reaches (Stocked and Non-native range) will receive focused enforcement effort as needed.

Water management

Staff will work in a collaborative nature to promote water management practices which mimic a natural river flow regime or flows which trigger spawning for habitats capable of supporting natural recruitment and maintain adequate low summer base flow in all reaches to maintain adequate levels of dissolved oxygen and temperature to promote sturgeon survival and recruitment. White Sturgeon recruitment is influenced by flow magnitude, the range of flow fluctuations, duration of flows at certain thresholds, timing, and coinciding water temperatures. The conservation and persistence of White Sturgeon in Idaho will depend upon adequate magnitude and frequency of high flows to ensure that sufficient recruits are produced to maintain populations. Modifications of the Snake River's hydrograph and temperature regimes have substantial benefits for society including hydropower and irrigation. Considering these benefits and uses, it is unlikely that successful wild sturgeon spawning and recruitment will be restored throughout their historical range in Idaho for the foreseeable future. Instead, IDFG will focus on conserving Core Wild populations by working with partners to ensure that adequate flows and temperatures occur at frequencies that allow recruitment sufficient to maintain or increase population abundances.

Improving flow and temperature regimes for sturgeon is complicated given the multiple uses of the Snake River. It is unlikely that system changes could be of significant magnitude to allow for spawning during low-flow conditions (e.g., periods of drought). Instead, staff should focus efforts to maximize recruitment during moderate or high flow periods by engaging water managers and water users to ensure that sturgeon spawning and rearing needs are considered in operations and decision-making processes. Flow triggers are extremely important for natural recruitment, and flow augmentation in the spring for other purposes (e.g. juvenile salmonids) in other river systems have been documented to trigger sturgeon spawning events (Jackson et al. 2016). Given the importance of adequate river discharge for successful sturgeon spawning and rearing IDFG will continue to emphasize water release and management strategies that enable natural recruitment sufficient to maintain or increase populations in all reaches.

Habitat restoration

IDFG supports habitat restoration to maintain healthy and viable White Sturgeon populations. IDFG will work with state and federal regulatory management agencies and the Native American Tribes to optimize White Sturgeon spawning success and place emphasis on projects which maintain population connectivity between reaches. These factors are critical to maintaining population abundance and genetic diversity in reaches supporting natural recruitment or stocked reaches (Jager et al. 2001). In the Bliss and Hells Canyon Core Wild Reaches, of the Snake River, IDFG will promote protection of habitat conditions in these areas. IDFG staff will continue to provide technical support and input to state and federal regulatory agencies regarding land management, water quality, hydropower operations, and flow management.

Partner coordination

Management of Snake River White Sturgeon relies on partnerships between state and tribal partners as well as the Idaho Power Company (IPC).

- State management jurisdiction is shared between IDFG, Washington Department of Fish and Wildlife (WDFW; downstream of McDuff Rapid) and Oregon Department of Fish and Wildlife (ODFW; upstream of McDuff Rapid) in Hells Canyon; and between IDFG and ODFW from Brownlee to Swan Falls and Oxbow to Hells Canyon dams. Reaches upstream of Swan Falls are solely managed by IDFG.
- The Nez Perce Tribe (NPT) shares management in part of the Snake River. Nez Perce Tribe management objectives and priorities for White Sturgeon in this area are outlined within their 2005 management plan (NPT 2005).
- Idaho Power Company is mandated to monitor White Sturgeon populations associated with hydropower facilities. The Snake River Sturgeon Conservation Plan sets objectives and measures for White Sturgeon monitoring associated with IPC projects (IPC 2015). Research and monitoring associated with IPC projects has been integral to developing White Sturgeon management priorities and addressing data gaps associated with White Sturgeon management in the Snake River.

ADULT ABUNDANCE OBJECTIVES

IDFG has worked collaboratively with IPC to develop adult sturgeon abundance objectives for Snake River reaches (Table 1). In most reaches, abundance objectives were generated by estimating a habitat carrying capacity by reach based on observed adult sturgeon density in the C.J Strike Dam to Bliss Dam reach river habitat. Only river habitat >2m depth was used to estimate adult abundance objectives due to limited sturgeon use of reservoir habitat in most reaches. The Bliss Reach was selected as the reference reach given it contains the healthiest population of naturally reproducing White Sturgeon in the mid-Snake River. Observed adult sturgeon density from the Bliss Reach (0.84 adults/hectare) was expanded to the area of river habitat existing in other mid-Snake River reaches to generate an adult abundance objective. Reservoir habitat adult abundance objectives were included for the Hells Canyon and Bliss reaches total Abundance Objectives since White Sturgeon reservoir use has been documented in these reaches. Reservoir habitat in these reaches was expanded by the C.J. Strike Dam to Bliss Dam reach sturgeon density of 0.55 fish/ha to generate abundance objectives for these two reaches.

The Core Wild reaches of Lower Granite Dam to Hells Canyon Dam and C.J. Strike Dam to Bliss Dam will be managed to meet adult abundance objectives through natural recruitment of wild fish. These reaches are expected to retain the environmental characteristics needed to maintain recruitment events. Management strategies to meet adult abundance objectives in the Lower Granite Dam to Hells Canyon Dam reach will involve translocation of wild fish entrained downstream back into the reach or translocation of individuals within the reach into habitat which is currently operating below capacity (e.g., Lower Granite Reservoir).

Stocked Reaches will rely on the repatriation hatchery program as the mechanism to achieve adult fish abundance objectives in the future. Modeled predictions of annual White Sturgeon juvenile stocking densities in mid-Snake River reaches have been estimated to achieve abundance objectives by 2060 (IPC 2021). Monitoring of stocked reaches will inform stocking densities in the future and adjustments to stocking objectives will be coordinated with IPC.

Stocking priorities will guide sturgeon releases in the event there are insufficient fish to meet all stocking objectives on an annual basis (Table 1). Priority 1 will be reaches that require stocking to achieve White Sturgeon abundance objectives for conservation and angling opportunity and exhibit infrequent to no natural recruitment. Priority 2 will be placed on reaches that require stocking to meet White Sturgeon abundance objectives for conservation and angling opportunities and have no natural recruitment and expected lower survival of releases. Finally, Priority 3 will be non-native reaches or in locations within native range that provide marginal water quality. Assessment of adequate water quality in Priority 3 reaches would be required prior to initiation of any stocking. White Sturgeon releases upstream of Shoshone Falls will be continued when higher priority stocking needs are met, and excess releases are available. Annual Juvenile Stocking Objectives specified in this plan will be updated on an as needed basis considering survival data from population assessments and annual availability of fish for stocking through the repatriation aquaculture program.

Any new White Sturgeon release locations outside of their historical range and existing occupied reaches will be vetted through the American Fisheries Society 7-step process (AFS Policy Statement).

Table 2. Summary statistics of Snake River White Sturgeon reaches included to estimate adult abundance objectives, juvenile stocking objectives, and stocking priority. Adult abundance estimated by applying the percent of fish occupying adult size classes (fish >162 cm FL) to the most recent total population estimate (fish >95 cm).

Reach	Management Category	Population Estimate	% >162cm	Adult Abundance	Adult Abundance Objective	Difference	Juvenile Stocking Objective	Stocking Priority
Lower Granite Dam to Hells Canyon Dam	Core Wild	3,816[1]	34%	1,333	3,443[2]	-2,146	n/a	0
Hells Canyon Dam to Oxbow Dam	Stocked	15	67%	10	n/a	n/a	0	2
Oxbow Dam to Brownlee Dam	Stocked	0	0%	0	n/a	n/a	0	2
Brownlee Dam to Swan Falls Dam	Stocked	312	62%	193	2,900	-2,707	1,300	2
Swan Falls Dam to C.J. Strike Dam	Stocked	240	43%	103	460	-357	320	1
C.J. Strike Dam to Bliss Dam	Core Wild	3,442	56%	1,928	2,065[2]	-137	n/a	0
Bliss Dam to Lower Salmon Falls Dam	Stocked	99	56%	55	110	-55	50	1
Lower Salmon Falls Dam to Upper Salmon Falls Dam	Stocked	27	63%	17	260	-243	115	1
Upper Salmon Falls Dam to Shoshone Falls	Stocked	366	42%	154	450	-296	200	1
Shoshone Falls to Upper Power Plant Dam (Idaho Falls)	Non-native Range	n/a	n/a	n/a	500	n/a	200	3

[1] Estimate includes Lower Salmon River

[2]Reservoir habitat included in adult abundance objective calculation for Lower Granite Dam to Hells Canyon Dam and C.J. Strike Dam to Bliss Dam

REACH MANAGEMENT PLANS

Because the various Snake River reaches have a range of characteristics and are essentially isolated from one another, this plan prescribes White Sturgeon management on a reach-by-reach basis. Within the native distribution of White Sturgeon, population and recreational fishery objectives are developed for each reach based on the physical habitat, flow conditions, as well as current status of the population and fishery. Additionally, this management plan addresses expanded White Sturgeon range into new waters outside their historical distribution to provide recreational opportunities. Reaches are described using upper and lower boundaries but are commonly referred to by their upper boundaries. For example, the reach between Lower Granite Dam to Hells Canyon Dam is referred to as the "Hells Canyon Reach".

LOWER GRANITE DAM TO HELLS CANYON DAM

Reach metrics

Management Designation: Core Wild
Adult Population Abundance Objective: 3,443 fish > 162cm FL (river and reservoir habitat)
Adult Population Estimate, Year: 1,333 fish > 162 cm FL, 2014
Stocking Objective: None

Reach description

Completion of Hells Canyon Dam in 1967 (rkm 398) and Lower Granite Dam in 1975 (rkm 173) isolated White Sturgeon into a 225 km reach of the Snake River which is referred to as the Hells Canyon reach in this document (Figure 4). The state of Washington maintains management jurisdiction downstream of the Snake and Clearwater rivers confluence. Lower Granite Dam backs up water in the Snake River for about 64 km to about 8 km upstream of where the Clearwater River enters. This leaves about 161 km in the Hells Canyon reach as free flowing river. From Lower Granite Reservoir at Lewiston, ID, to the Hells Canyon tailrace, the Snake River forms the Washington-Idaho border for the downstream 59 km and the Oregon-Idaho border for the upper 114 km. Major tributaries entering the Hells Canyon reach include the Clearwater, Grande Ronde, Salmon, and Imnaha rivers, although only the Salmon River currently supports White Sturgeon.

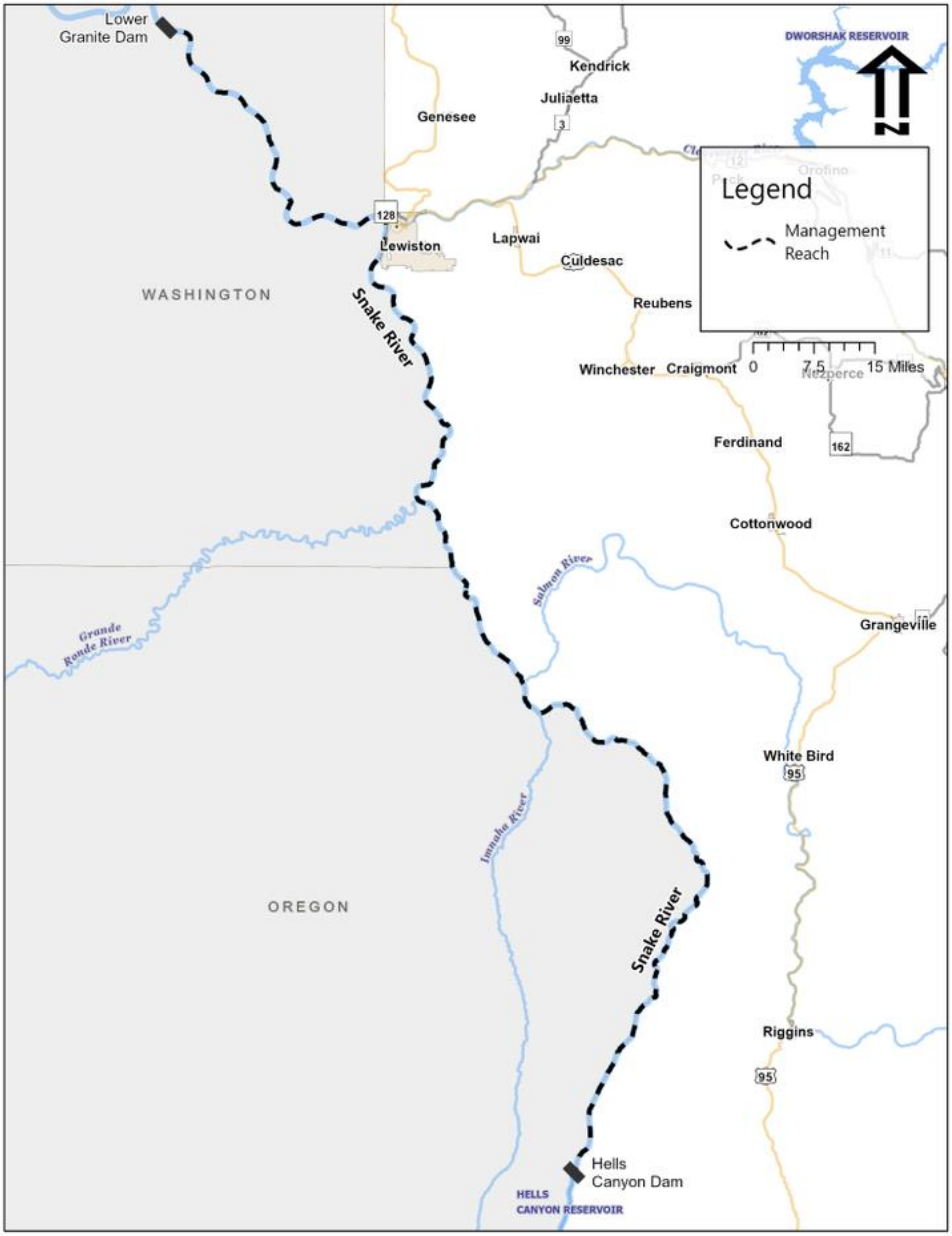

Figure 4. Map of Hells Canyon reach of the Snake River from Lower Granite Dam (downstream) to Hells Canyon Dam (upstream).

White Sturgeon in Hells Canyon Reach have unimpeded access to the Salmon River, and therefore, will be treated for management purposes as one population. The Salmon River is the longest (684 km; 36,000 km^2) undammed river in the Columbia River basin. The Salmon River from its mouth to Little Salmon River occurs entirely in Idaho and is about 132 km in length (Figure

5). This reach is comprised entirely of free-flowing river with a mix of shallow water (<3 m) riffle/run and deep pool (>10 m) habitat. A road parallels 36% of this reach from Hammer Creek boat ramp (rkm 83.5) upstream to the Little Salmon River. The lower 84 km of the Salmon River has little to no road access. No large tributaries (rivers) enter the Salmon River in this reach. A few small towns occur along the river including White Bird and Riggins.

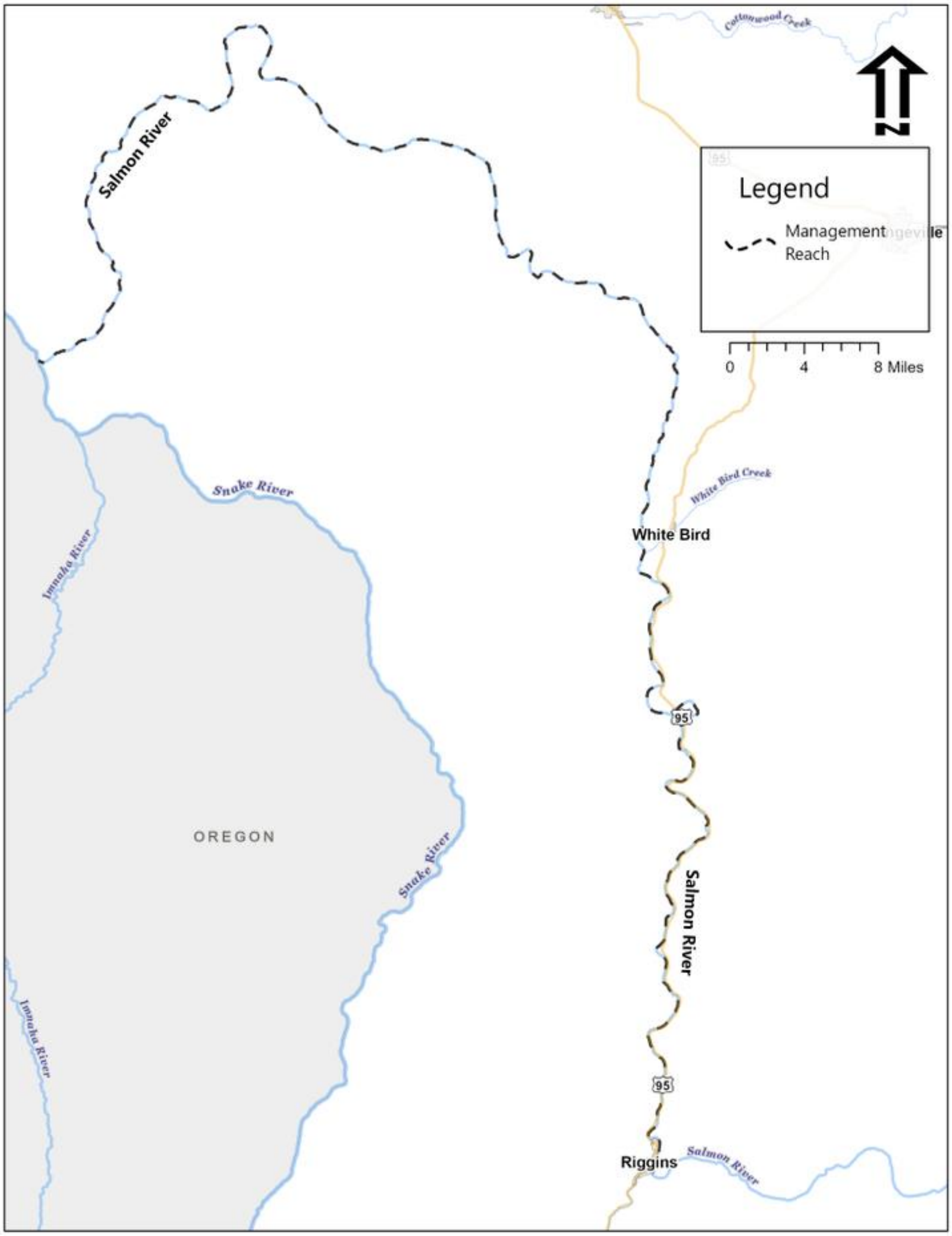

Figure 5. Map of lower Salmon River from the confluence with the Snake River to the town of Riggins.

Due to its unimpounded nature, stream flow and temperatures in the lower Salmon River are influenced largely by annual precipitation, snowmelt, and weather patterns. Daily average water temperatures tend to reach their maximum in late July/early August (~22°C) and low in late December/early January (< 0.5°C). Average discharge in the Salmon River at White Bird

(USGS13317000 Salmon River at White Bird) is 11,000 cfs and contributes about 40% of the flow to the Snake River at their confluence. This entire reach of river occurs in a steep canyon with little natural floodplain available. The river can be characterized as having a diversity of habitats with high velocity rapids, deep slow pools, and long runs.

Upstream impoundments on the Snake River influence both water temperature and the annual hydrograph pattern of the Snake River below Hells Canyon Dam. Hells Canyon Dam operates as a peaking facility throughout the year except during the fall Chinook Salmon spawning window (~Oct – Dec) when releases are held constant. Power peaking typically causes river flows to fluctuate from 3,000 to 7,000 cfs daily. The upstream impoundments on the Snake River tend to reduce peak flows while extending the duration of high flows later in the spring. In the past 30 years, annual flows at Hells Canyon Dam (USFS 13290450) have averaged 17,300 cfs whereas flow from the Salmon River (USGS13317000 Salmon River at White Bird) averaged about 11,000 cfs. Average flows at the Snake River at Anatone (USGS 13334300) have averaged about 32,700 cfs. Water temperatures in the Snake River upstream of the Salmon River tend to be warmer than the Salmon River except during March and July (Figure 6). This would suggest that flows from Hells Canyon Dam tend to provide water temperatures to the Hells Canyon Reach that would shorten the summer growing season for sturgeon but lengthen it in the spring and fall when compared to the Salmon River.

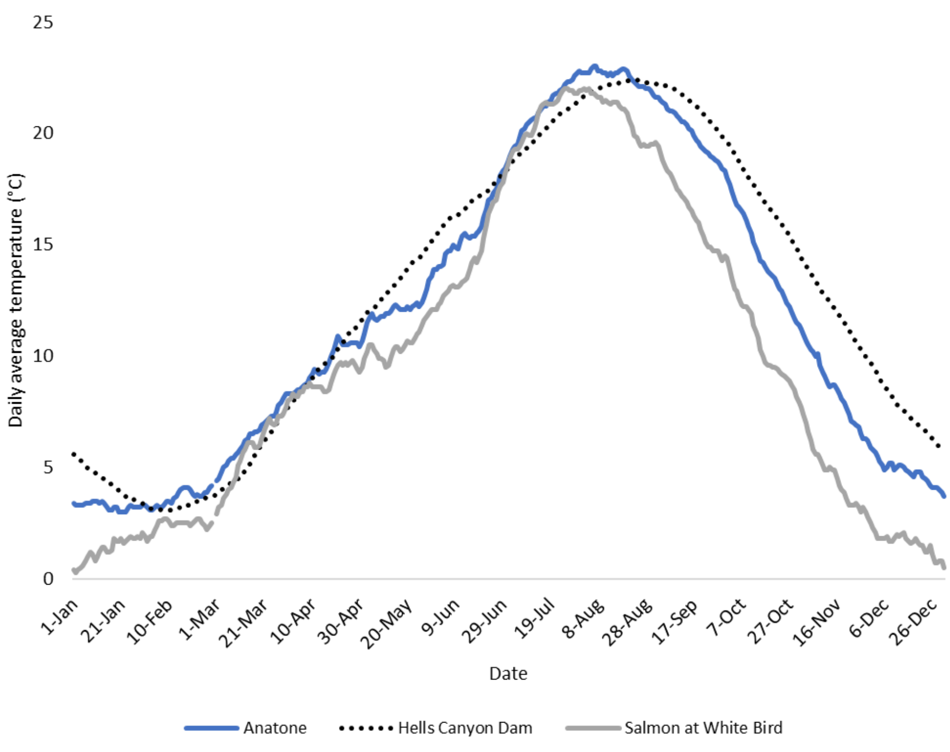

Figure 6. Daily average water temperatures from 2000 to 2020 at Hells Canyon Dam and in the Salmon River at White Bird (USGS 13317000).

Despite alterations as a results of dam construction, the free-flowing section of the Hells Canyon Reach is represented by a diversity of habitats and provides the most natural habitat that remains among the impounded Snake River reaches inhabited by White Sturgeon (IDFG 2008).

POPULATION ASSESSMENTS

Abundance Estimates

Hells Canyon

Multiple White Sturgeon assessments have occurred in the Hells Canyon reach since 1977 to describe population characteristics (Coon et al. 1977; Cochnauer et al. 1985; Lukens 1985; Lepla 1994; Lepla et al. 2001; Everett et al. 2003; Bentz 2015). Direct comparison between these assessments is difficult due to differences in sampling methodologies; however, three assessments since 1985 suggest the population has been relatively stable at around 4,000 fish > 70 cm TL (Figure 7; Lukens 1985; Lepla et al. 2001; Everett et al. 2003; Bentz 2015). Interestingly, White Sturgeon population estimates in the Hells Canyon reach are similar to population estimates in each of the three lower Snake River dam complexes downstream of Lower Granite Dam even though the Hells Canyon reach is three times longer (DeVore et al. 1999; Shade et al. 2020). The Hells Canyon reach is currently below adult sturgeon abundance objectives (Table 1). Monitoring information in the reach suggests underutilization of Lower Granite Reservoir by adult sturgeon. Increased utilization of Lower Granite Reservoir has the highest potential for increased production.

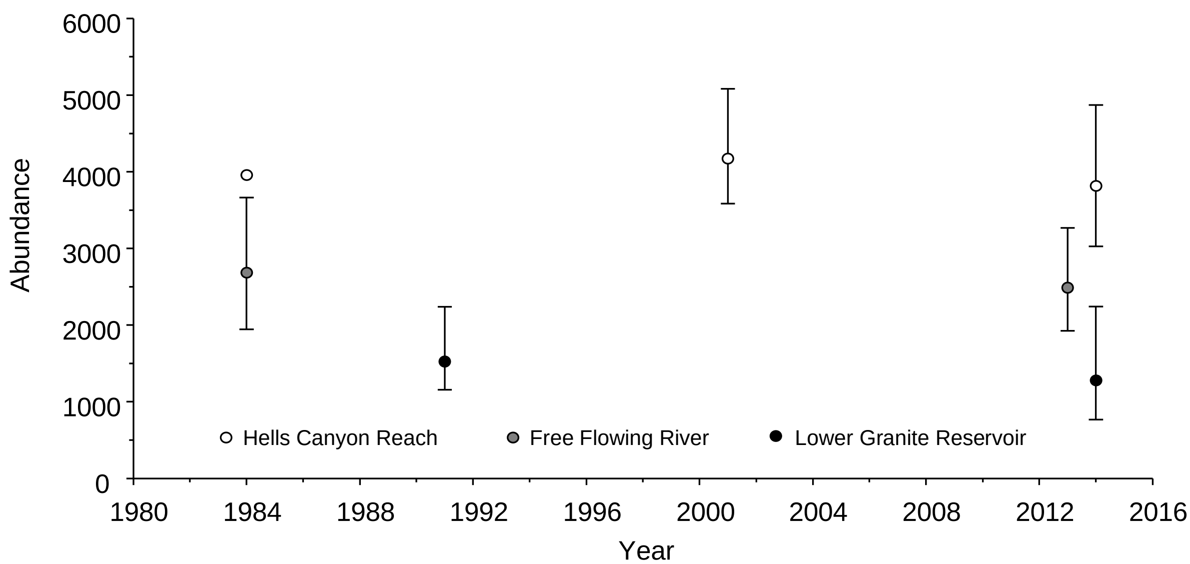

Figure 7. Population estimates of White Sturgeon > 70 cm TL within the Hells Canyon Reach of the Snake River in 1984 (Lukens 1985), 1991 (Lepla 1994), 2001 (Lepla et al. 2001; Everett et al. 2003) and 2014 (Bentz 2015). (courtesy of Idaho Power Company)

Lower Salmon River

Two systematic assessments have occurred in the lower Salmon River to describe White Sturgeon population characteristics. One occurred from the mouth upstream 185 km from 1997 through 2001 (Everett et al. 2003) and the other occurred from the mouth upstream 37 km from 2012 through 2014 (Bentz 2015). Additionally, the IDFG has captured and PIT tagged sturgeon in the lower Salmon River occasionally since 1991 (IDFG unpublished data). These three sampling efforts suggest that White Sturgeon are most common in the lower 45 km of this river with densities decreasing considerably farther upstream. Through these efforts, only one fish was captured upstream of rkm 83 although guides and locals regularly report catching sturgeon between rkm 83 and 131. There have been reports of sturgeon as far upstream as the town of Salmon and into the Middle Fork Salmon River, but it is believed that these are isolated occurrences.

Bentz (2014) estimated that in the lower 37 km of the Salmon River there were 105 White Sturgeon > 70 cm FL (32-523 95% CI). Everett et al. (2003) did not estimate population abundance in the lower Salmon River; however, their set line catch rates of 6.6 fish/1,000 h were slightly higher than the 5.2 fish/1,000 h observed by Bentz (2015).

Size Structure and Growth

Hells Canyon

Four different assessments dating back to 1977 provide information to indicate that the size structure of the White Sturgeon population in the Hells Canyon reach has gradually increased since catch-and-release seasons were set in 1971 (Figure 8). In 1977, 14% of the fish sampled were > 92 cm TL whereas in 2014, 63% of the sturgeon sampled were > 92 cm TL (Coon et al. 1977; Lukens 1985; Lepla et al. 2001; Everett et al. 2003; Bentz 2015). When one considers that the population has remained relatively stable over time, an increasing abundance of sturgeon > 92 cm TL conversely means the number of sturgeon < 92 cm TL has declined. It is unclear to what degree this decline is a response to the scarcity of spawning-sized fish that occurred 20-40 years ago or if some other factors have been influencing recruitment or growth of fish > 92 cm TL.

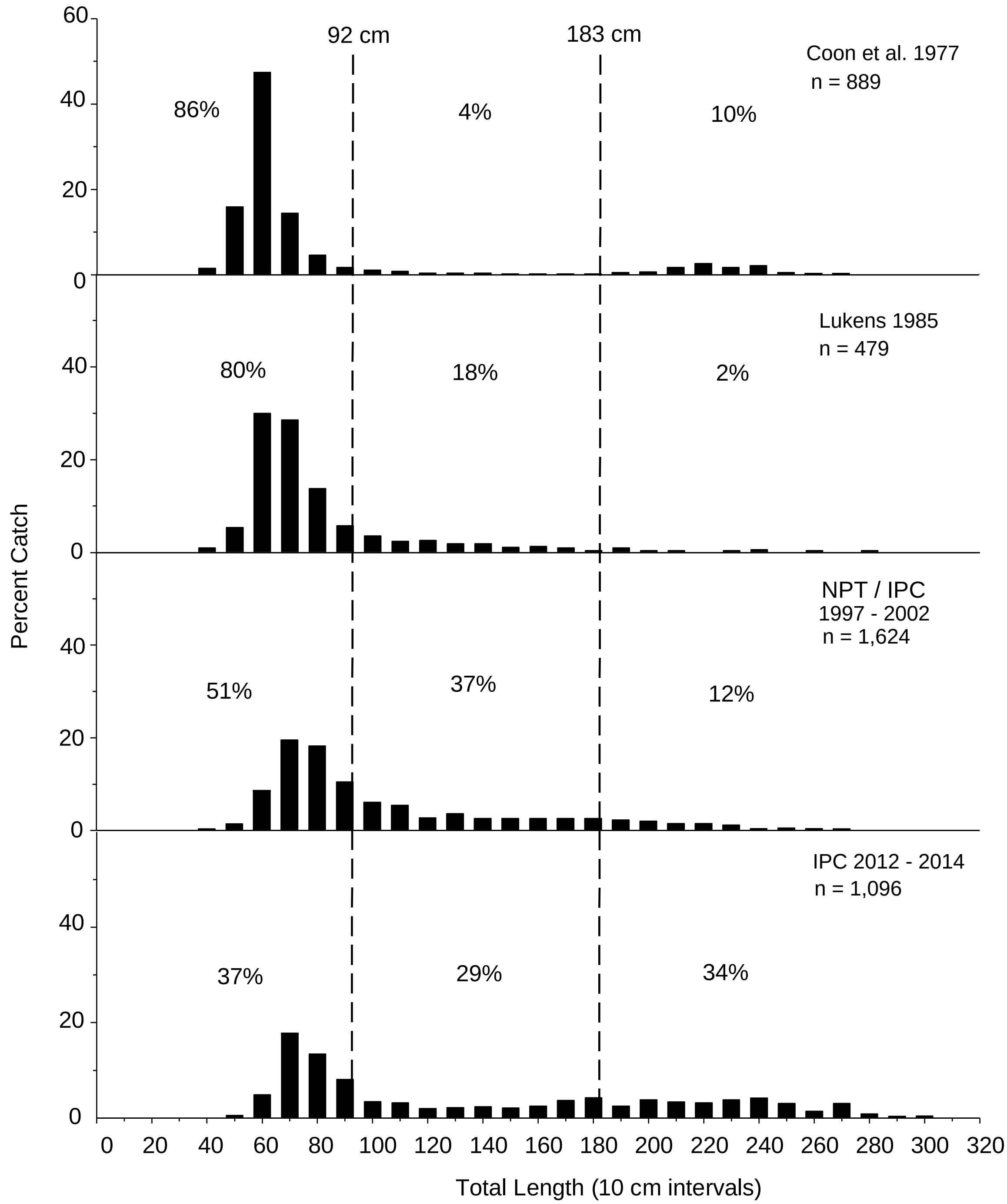

Figure 8. Length-frequency histograms of White Sturgeon sampled in the Hells Canyon Reach of the Snake River in 1977 (Coon et al. 1977), 1985 (Lukens 1985), 1997-2002 (Lepla et al. 2001; Everett et al. 2003), and 2012-2014 (Bentz 2015). Dashed lines represent life stage length breaks (Juvenile <92cm, subadult 92-183cm, and adult >183cm). (courtesy of Idaho Power Company)

Growth rates of Hells Canyon White Sturgeon vary between river and reservoir rearing areas, with riverine growth rates being significantly lower than other Snake River reaches. Recaptures of previously PIT-tagged fish have been used to estimate annual growth increments in the reach (Bates 2014; Bentz 2015). On average, riverine White Sturgeon less than 90 cm FL grew less than 2 cm FL a year (Figure 9; B. Bentz, IPC, unpublished data). Once riverine sturgeon exceed 90 cm FL, their growth steadily increased and peaked at about 5 cm a year in the 130 cm FL size class. White Sturgeon utilizing the Lower Granite Reservoir had growth rates that were 2 to 13 times higher than fish rearing in free-flowing section of river until they reached 120 cm FL. After exceeding 120 cm FL, sturgeon rearing in the river and reservoir had more similar growth rate; and when they reached 190 cm FL, their annual growth rates were about identical (Figure 9).

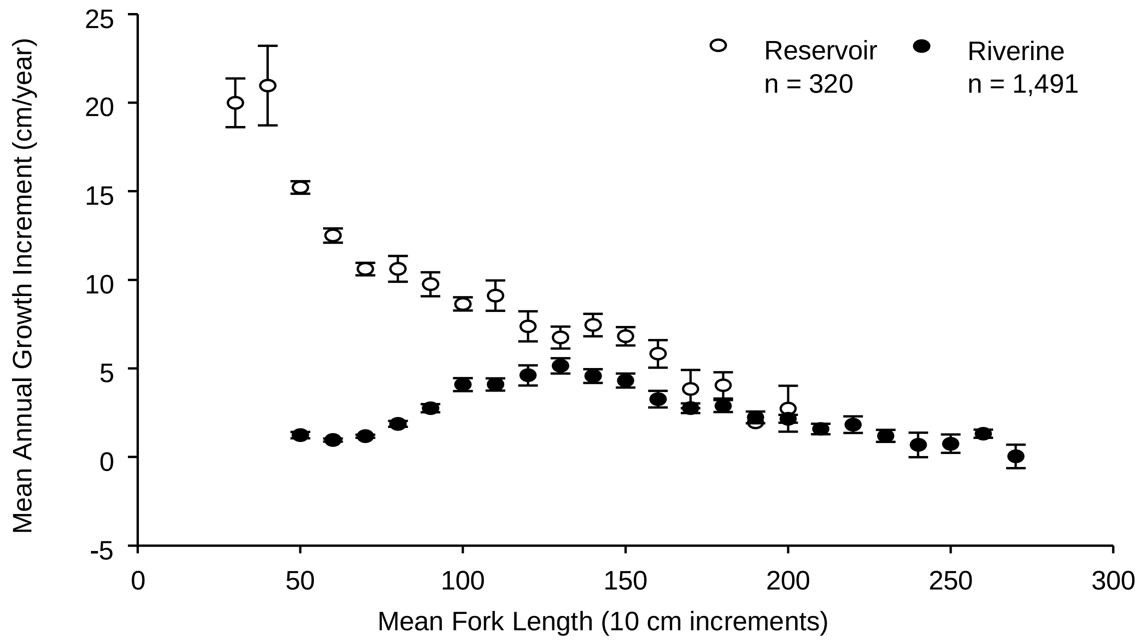

Figure 9. Mean annual growth increments of White Sturgeon collected in the free-flowing (riverine) and reservoir sections of the Hells Canyon Reach of the Snake River based on fish tagged and recaptured between 1990 and 2022. (courtesy of Idaho Power Company)

Growth rates based on recaptured fish were used to model length-at-age for sturgeon in the Hells Canyon reach (Figure 10; Bates et al. 2014). Based on this model, on average it would take 25 years for sturgeon to reach 100 cm FL and 46 years for females to reach 185 cm FL. Female sturgeon in the Hells Canyon Reach have been found to reach first maturity at lengths ranging from 170 to 200 cm FL. The 185 cm FL used in this analysis was the average of this range. It should be noted that this model used data from fish recaptured in both the river and reservoir. As such, if a sturgeon spent little to no time in the reservoir, it would take even longer to reach maturity.

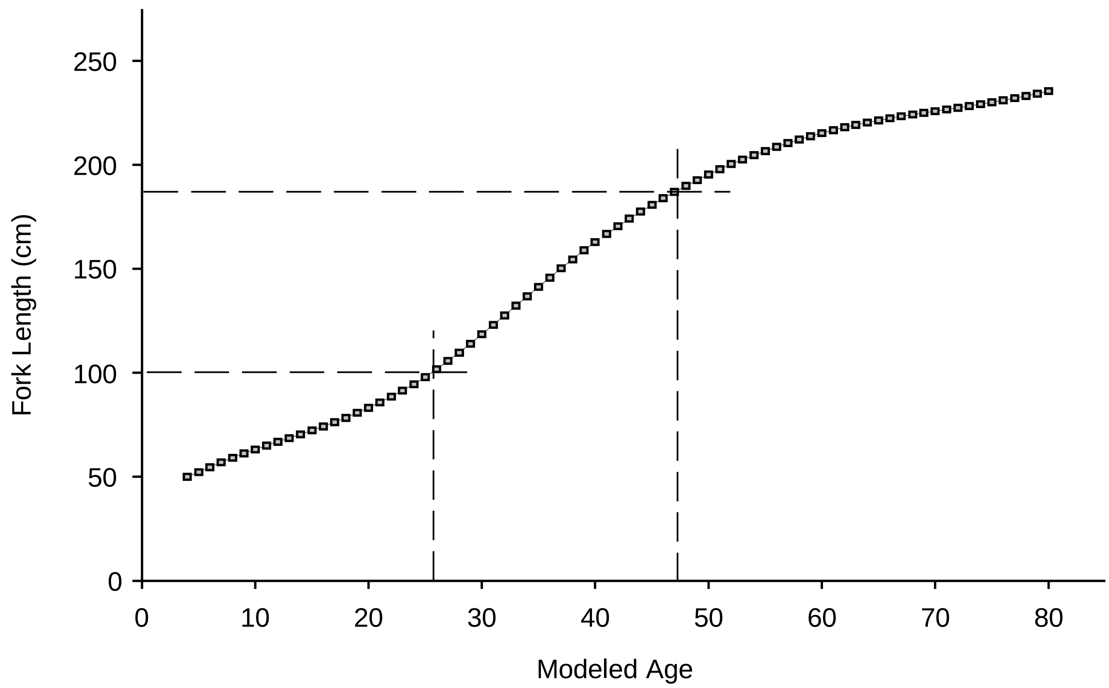

Figure 10. Modeled mean length-at-age of White Sturgeon in the Hells Canyon reach of the Snake River based on mean annual growth increments of recaptured fish between 1990 and 2012. Dashed lines display modeled age at subadult and adult size classes. (Bates et al. 2014, courtesy of Idaho Power Company)

Lower Salmon River

In lower Salmon River assessments, abundance results have remained similar, however size structure differences have been documented. The most recent assessment by Bentz (2014) did not document any catch of sturgeon < 100 cm FL (Figure 11) whereas about 13% of the fish collected 13 years earlier by Everett et al. (2003) were < 100 cm FL. No fish tagged by IDFG have been less than 100 cm FL (IDFG unpublished data).

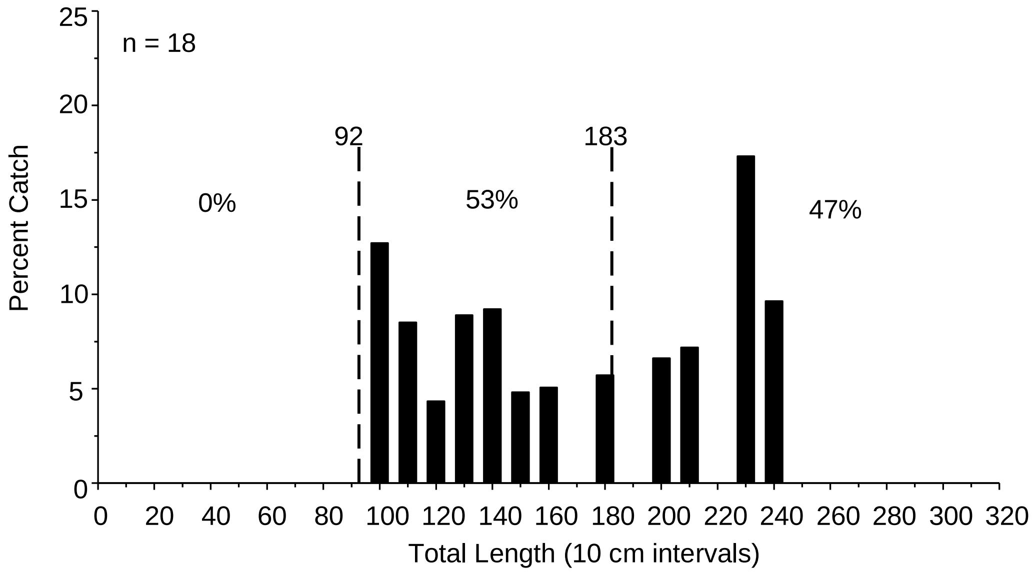

Figure 11. Length-frequency histogram of White Sturgeon sampled in the lower Salmon River during 2012-2014. Dashed lines represent life stage length breaks (Juvenile <92cm, subadult 92-183 cm, and adult >183 cm). (courtesy of Idaho Power Company)

Sturgeon density in the lower Salmon River (3.5 fish/km) was reported being 20% of what was observed in the free-flowing Hells Canyon reach (18.6 fish/km) during the same time frame (Bentz 2015). The main reason for this difference in density was because no sturgeon < 100 cm TL were collected in the Salmon River. When densities of just those sturgeon > 100 cm TL were compared between these two reaches, they were nearly identical (Bentz 2014). Sturgeon were found to have lower relative weights in the Salmon River than the Hells Canyon reach of the Snake River (Everett et al. 2003; Bentz 2015).

Movement between the Snake and Salmon rivers was evaluated through recapturing marked fish (Everett et al. 2003; Bentz 2015) and use of telemetry (Everett et al. 2003). This work documented no movement of fish between the rivers. Most fish moved less than 10 km throughout the studies although one radio tagged fish was tracked 35 km upstream from where it was tagged (Everett et al. 2003).

White Sturgeon utilize the lower Salmon River for spawning. Work in 2000 deployed egg matts between rkm 40.2 and 44.0 in the Salmon River to assess whether White Sturgeon spawning occurred there (Everett et al. 2003). Eggs were recovered on three different occasions from May 20 to June 21 (Everett et al 2003).

Survival

Annual survival rates of sturgeon in the Hells Canyon reach have been estimated to range from about 91% to 96% depending on fish size (Table 3; B. Bentz, IPC, unpublished data). These estimates are believed to be biased low and will likely increase as more fish are PIT tagged and recaptured (B. Bentz, IPC, personal communication). Using these annual survival rates and the modeled growth rates, about 2.5% of those female sturgeon that reach age-1 would survive to maturity (> 185 cm FL) whereas about 17.3% that rear in the reservoir would survive to maturity

(Figure 12). Rearing environment (river vs. reservoir) and documented growth rate differences between the two environments would greatly affect White Sturgeon survival and age at maturity.

Table 3. Annual estimated survival rates of different size classes of White Sturgeon (males and females combined) utilizing the Hells Canyon reach of the Snake River (courtesy of Idaho Power Company).

Life Stage	Total Length (cm)	Fork Length (cm)	Annual Survival
Juveniles	<108	<95	0.906
Sub-adults	108-183	95-162	0.927
Adults	>183	>162	0.955

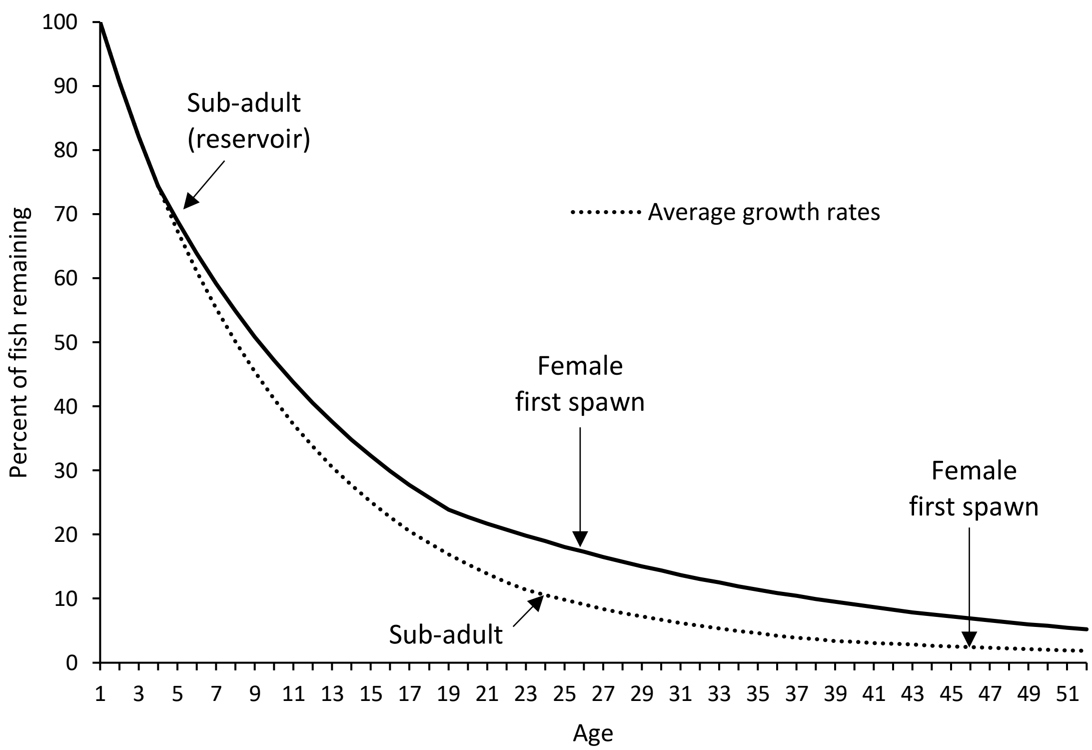

Figure 12. Modeled percent of female White Sturgeon (of those reaching age-1) surviving to adulthood based on length specific survival rates in the Hells Canyon reach of the Snake River (see Table 2) and using two different growth rate curves: one that assumes that fish grow at the average growth rates described in Figure 6 and the other where fish grow to 100 cm in 5 years (reservoir growth) and then continue at the average growth rate.(courtesy of Idaho Power Company)

Recruitment and Juvenile Movement

White Sturgeon recruitment and early rearing in the Hells Canyon reach are not well understood. Spawning is believed to occur throughout much of the free-flowing river based on the capture of newly spawned eggs during egg matt sampling (Everett et al. 2004; Lepla and Chandler 2001). After hatching, larval drift can result in long downstream movements. Substantial numbers of larval sturgeon drift into Lower Granite Reservoir (Bates 2018), but it is unclear what portion of total larval drift within the Hells Canyon reach this represents. To better understand White Sturgeon recruitment in the Hells Canyon reach, annual sampling with small-mesh gill nets was initiated in Lower Granite reservoir in 2014. Sampling efforts from 2014 to 2016 collected no age-0 or age-1 sturgeon whereas efforts from 2017 to 2020 collected age-0 fish and/or age-1 fish indicating that some level of recruitment had occurred in those years (Hughes 2021). These observations suggest that successful recruitment is directly related to higher spring (May-July) river flows which occurred in 2017-2020 (Hughes 2021). However, sampling efforts in the early 1990s did document White Sturgeon recruitment during low flow years (Lepla 1994). It is currently unknown if flow triggers or changes to the reservoir environment such as spring spill at Lower Granite Dam or increased abundance and diversity of non-native species (Erhardt and Tiffan 2016; Tiffan et al. 2017a; Tiffan et al. 2017b) in Lower Granite Reservoir are influencing changes observed in more recent surveys. Because sampling in the reservoir has detected successful recruitment during a variety of environmental conditions, it is still unclear whether the bottleneck that limits recruitment during low-flow years is occurring in the river, reservoir, or both.

Larval and juvenile White Sturgeon movement patterns are complex and affected by the presence of Lower Granite Dam and reservoir. White Sturgeon tagged in the reservoir have been found to migrate upstream of Lower Granite Reservoir at various ages/sizes to rear in the free-flowing section of river, and upstream migrations of juvenile sturgeon of over 100 km within a one- or two-year period have been documented (B. Bentz, IPC, unpublished data). General movement patterns of sturgeon between the reservoir and river are unknown, although it is evident that at some time fish rearing in the reservoir will migrate into the river for spawning or rearing purposes. Hells Canyon reach White Sturgeon also are known to be entrained through or over Lower Granite Dam. PIT-tag detections of adult sturgeon and incidental catch of dozens of juvenile sturgeon annually at the smolt bypass facility have verified entrainment from upstream (Hughes 2021). In addition, sampling in the Snake River reservoirs downstream of Lower Granite Dam has recaptured sturgeon originally PIT-tagged upstream of Lower Granite Dam (Shade et al. 2020). It is unknown what portion of the sturgeon that originate from the Hells Canyon reach pass downstream of Lower Granite Dam. However, it is suspected that the White Sturgeon populations in the Snake River reservoirs downstream of Lower Granite Dam are largely supported by entrainment of fish from the Hells Canyon Reach (DeVore et al. 1999).

WATER QUALITY

In general, complex habitat and influence of the free-flowing Salmon River entering into the Hells Canyon reach have mitigated quality impairment compared to upstream reaches. The reach is not limited by anoxic summer water conditions. However, the reach remains listed for TMDL exceedances for temperature and mercury (IDEQ 2004). Although listed for temperature exceedances for coldwater species, summer temperatures do not reach levels which impair sturgeon in the reach. Pollution-threshold exceedances from upstream reaches persist in the Hells Canyon reach; however, they are not believed to be limiting White Sturgeon in the reach compared to other issues.

Elevated mercury concentrations have been found to occur in White Sturgeon in the Hells Canyon reach (Bentz 2015). Anoxic conditions in Brownlee, and Hells Canyon reservoirs foster methylation, the conversion of elemental mercury into methylmercury, which results in increased accumulation in aquatic organisms. Mercury concentrations exceeding Idaho and Oregon standards were found to occur in adult sturgeon within the Hells Canyon reach (Bentz 2015). These concentration levels have been found to negatively influence recruitment in other species though potential impacts to sturgeon recruitment and survival are unknown.

FUTURE WORK

Population Monitoring

- Continue population assessments in the Hells Canyon reach at 10-year intervals.
    - Tag and recapture White Sturgeon in the Hells Canyon reach to assess growth, movement, and mortality.
    - Estimate long-term trends in the White Sturgeon population abundance and size structure in the Hells Canyon reach after completion of the 2024-2025 assessment.

- Index recruitment on an annual basis and determine primary causes for variations in recruitment in the free-flowing river and reservoir across a range of flow conditions.
    - Conduct fall gill netting in Lower Granite reservoir to understand the frequency and magnitude of recruitment relative to river flow.
    - Evaluate the invertebrate and fish communities in Lower Granite Reservoir to assess change since the early 1980s and early 1990s.
    - Compare diet and growth of juvenile sturgeon rearing in the river and reservoir to evaluate potential density-dependent growth.
    - Evaluate mercury and selenium concentrations in White Sturgeon and potential influence on survival and recruitment.

- Assess the level of White Sturgeon entrainment that occurs through Lower Granite Dam.
    - Work with Washington Department of Fish and Wildlife to evaluate Hells Canyon Reach White Sturgeon entrainment into Lower Snake River reaches.
    - Assess feasibility of White Sturgeon trap and haul from downstream of Lower Granite Dam to the Hells Canyon reach to increase the effective spawning population.

Recreational Angling

- Collect creel data to estimate angler effort and catch.
- Continue to collect data on metal ingestion associated with recreational angling.

HELLS CANYON DAM TO OXBOW DAM

REACH METRICS

Management Designation: Stocked
Adult Population Abundance Objective: None
Adult Population Estimate, Year: 10 Sturgeon >162 cm FL, 2016
Stocking Objective: None

REACH DESCRIPTION

The ~40-km section of the Snake River from Hells Canyon Dam upstream to Oxbow Dam is known as Hells Canyon Reservoir and was formed with the completion of Hells Canyon dam in 1967 (Figure 13). Hells Canyon Reservoir is located in a steep, narrow canyon. The reach is comprised primarily of impounded reservoir habitat and minimal free-flowing river (<6 km). Hells Canyon Reservoir has a surface area of 976 hectares and a storage capacity of 167,720 acre-feet; maximum depth is 60 meters. The absence of riverine habitat and water quality impairment within the reach limit and possibly preclude White Sturgeon recruitment.

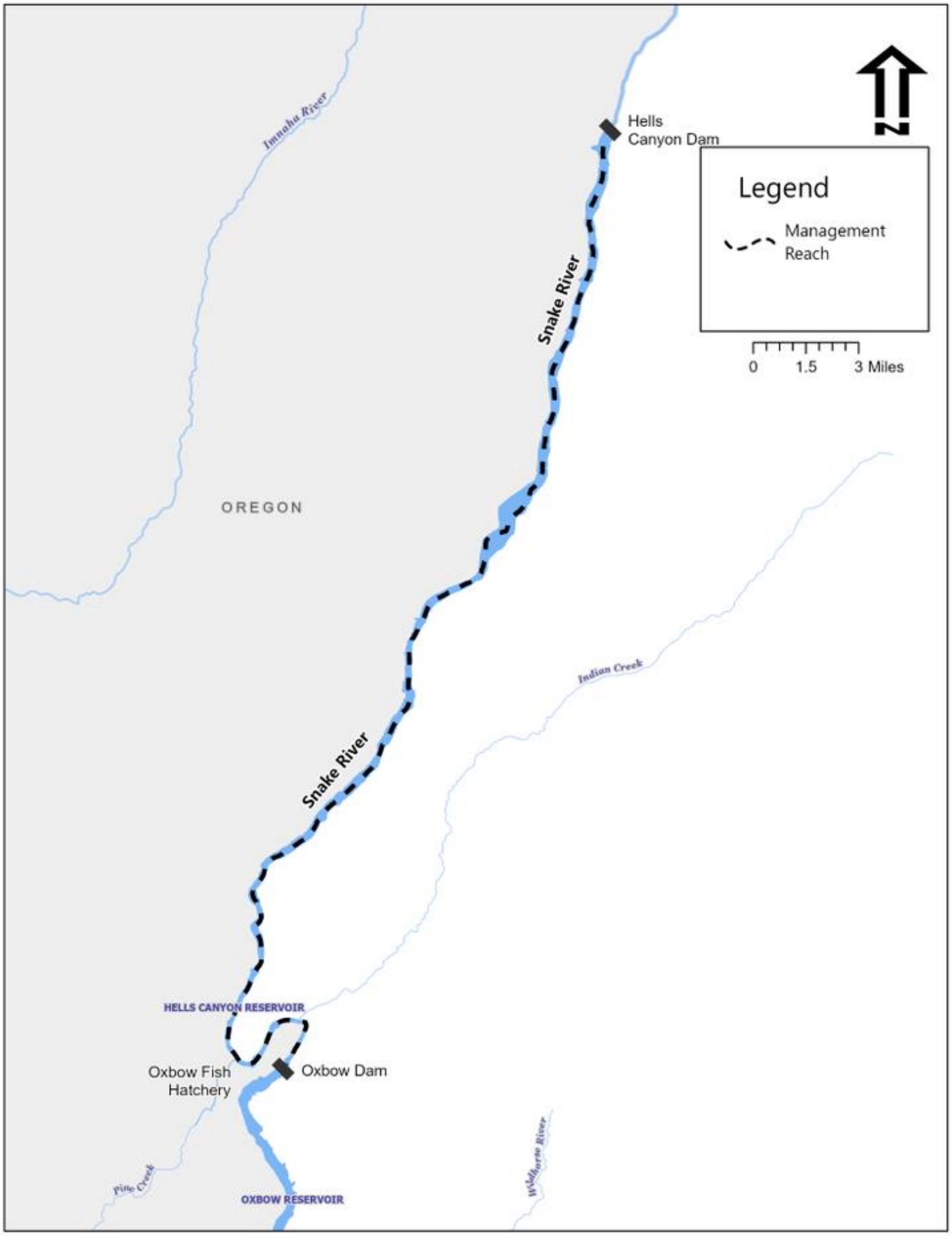

Figure 13. Map of Snake River, Idaho from Hells Canyon Dam (downstream) to Oxbow Dam (upstream).

POPULATION ASSESSMENTS

Abundance Estimates

Although it has not been routinely surveyed for White Sturgeon, abundance in Hells Canyon Reservoir has always been considered low. In 1992, Oregon Department of Fish and Wildlife personnel sampled with setlines below Oxbow Dam and captured a total of seven (1 hatchery and 6 wild). In 1998, IPC (Lepla et al. 2001) captured at total of four (1 hatchery and 3 wild). In the most recent IPC assessment in 2016, 3,954 hours of sampling effort were expended to catch a total of seven (n = 7; including 1 recapture) White Sturgeon (3 hatchery and 3 wild) (Bentz 2018a). The associated White Sturgeon abundance estimate was 15 individuals (95% CI: 7-72). All sturgeon captured in the above sampling events were captured in the upstream portion of Hells Canyon Reservoir – close to Oxbow Dam. There is no evidence of sturgeon natural recruitment in the reach. The origin of fish captured in Hells Canyon Reservoir is currently unknown. It is likely that captured White Sturgeon are from relic, naturally reproduced fish prior to the completion of Hells Canyon Dam or from entrainment.

Size Structure and Growth

Limited size and growth information are available in the reach due to small sample sizes of sturgeon collected during population assessments. Fish captured during the 2016 assessment were in sub adult and adult size classes (Figure 14). No evidence of recruitment has been observed in the reach.

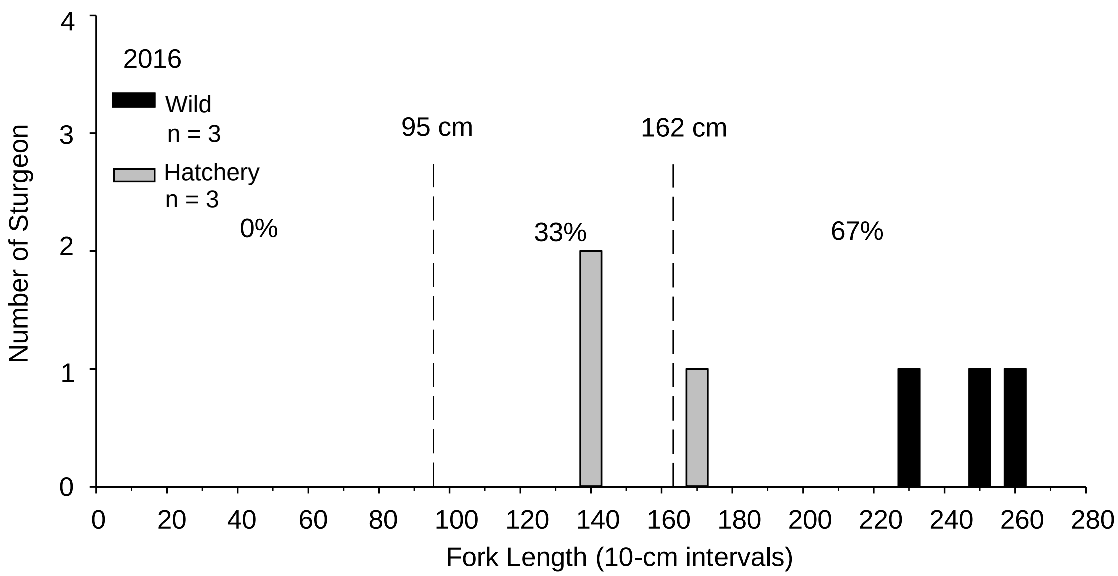

Figure 14. Length-frequency histogram of White Sturgeon captured with setlines in the Snake River between Hells Canyon and Oxbow dams, 2016 (courtesy of Idaho Power Company).

STOCKING

The Hells Canyon Dam to Oxbow Dam reach has received limited stocking. IDFG first stocked White Sturgeon into Hells Canyon Reservoir in 1991. One hundred White Sturgeon reared at Hagerman State Fish Hatchery (brood year 1990) were stocked at an average total length of 33.3 cm in May. In 1994, 40 adult White Sturgeon were stocked from a 'private hatchery' source, according to IDFG stocking records. In 2000, the Nez Perce Tribe stocked an additional 50 juveniles as part of a project to evaluate feasibility of a put-and-take fishery. The reach is currently not receiving any stocked releases of White Sturgeon due to water quality impairment.

WATER QUALITY

Water quality impairment is considered a limiting factor for White Sturgeon production within the reach. Hells Canyon Reservoir frequently experiences poor water quality as a result of conditions in Brownlee and Oxbow reservoirs upstream (Meyer et al. 2001). During low flow years, anoxic conditions lethal to White Sturgeon can compose 40-55% of the reservoir's bottom 2-m layer from July through September (Lepla and Chandler 2001). In addition, Hells Canyon Reservoir is listed for temperature exceedance of Idaho water quality standards for resident fish (IDEQ 2004). Due to the currently impaired water quality conditions, this reach will be ranked as a lower priority for stocking.

FUTURE WORK

- Coordinate with Oregon Department of Fish and Wildlife to develop and implement a routine and standardized sampling design to increase understanding of White Sturgeon status in the reach.
- Support IPC White Sturgeon population monitoring at 10-year intervals as indicated within the FERC License for Hells Canyon Dam. IDFG supports continued implementation of the IPC sampling rotation (once every 10-yrs) to maintain baseline data on White Sturgeon in the reach.
- Monitor water quality within the reach to determine the efficacy of White Sturgeon stocking
- Work with partners to implement water management strategies which improve water quality and promote a White Sturgeon fishery within the reach
- In years with high availability, stock reach in an experimental fashion to determine whether supplemented sturgeon remain in Hells Canyon Reservoir and increase reach abundance or entrain.
- Determine the optimal size for releasing hatchery sturgeon.

OXBOW DAM TO BROWNLEE DAM

REACH METRICS

Management Designation: Stocked
Adult Population Abundance Objective: None
Adult Population Estimate, Year: 0 White Sturgeon sampled, 2016
Stocking Objective: None

REACH DESCRIPTION

The 19-km section of the Snake River from Oxbow Dam upstream to Brownlee Dam is known as Oxbow Reservoir (Figure 15). The majority of this reach is impounded with only a very small portion consisting of lotic habitat, immediately downstream of Brownlee Dam. Brownlee Dam was completed in 1959, and Oxbow Dam was completed in 1961. The surface area of Oxbow Reservoir is 465 hectares with a storage capacity is 58,385 AF at full pool. Inflow to the reservoirs depend on releases from Brownlee Dam, which vary depending on inflows, flood-risk reduction, and regional electricity demand. Abundance of White Sturgeon within the reach is very low or zero.

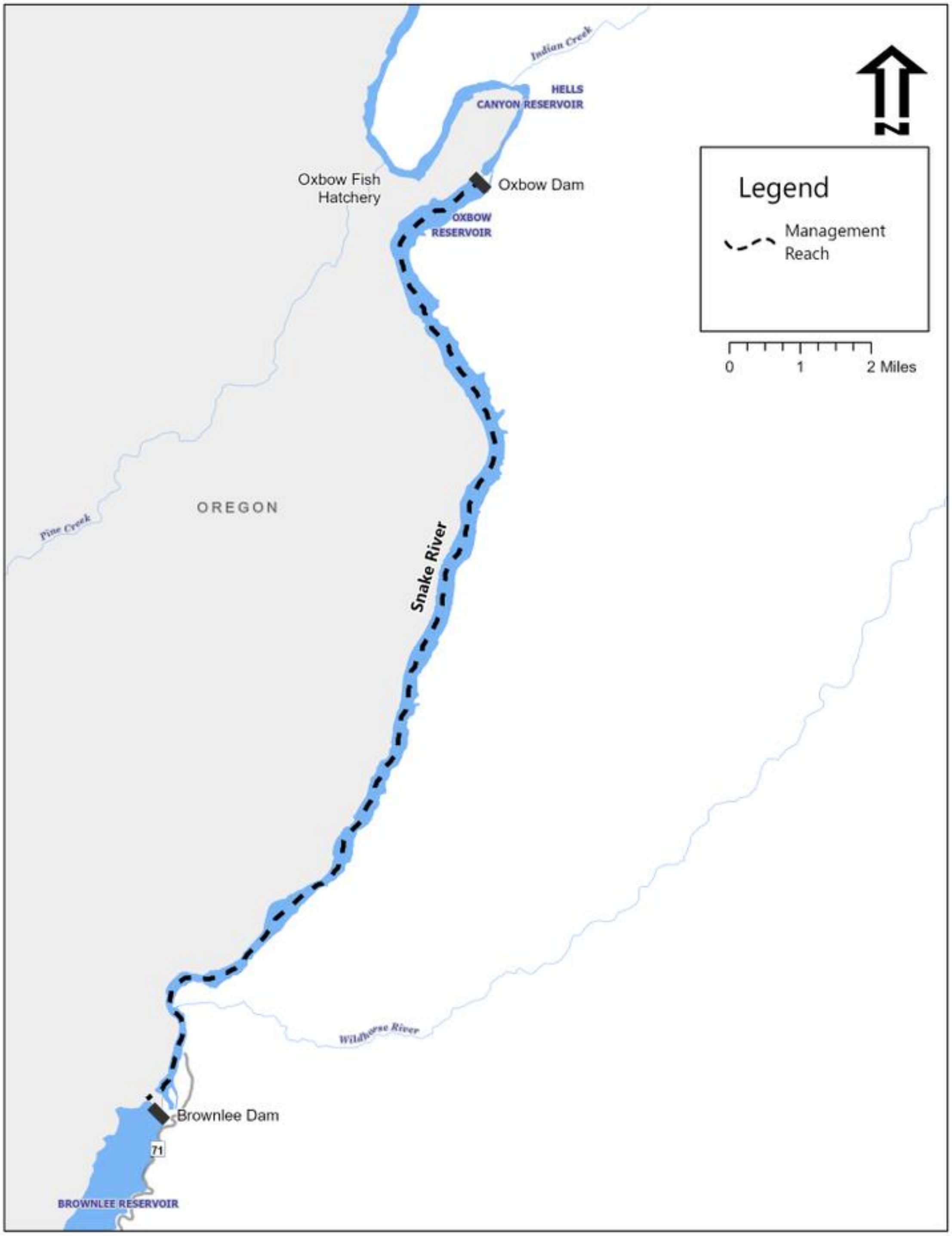

Figure 15. Map of Snake River, Idaho from Oxbow Dam (downstream) to Brownlee Dam (upstream).

POPULATION ASSESSMENTS

Population assessments in the reach have not documented White Sturgeon: however, sturgeon have been observed. Idaho Power Company biologists conducted the first White

Sturgeon population assessment in Oxbow Reservoir in 1998 and did not catch any sturgeon (Lepla et al. 2001). The most recent population assessment in 2016 expended 2,493 hours of set lining effort, and again did not capture any sturgeon. Six White Sturgeon mortalities were observed below the Brownlee Dam tailrace between 1994 and 2001 – most carcasses showing evidence of trauma likely as a result of turbine blade strikes. While uncertain, these fish may have entrained from upstream reaches.

These results suggest extremely low sturgeon abundance in Oxbow Reservoir, and a lack of natural recruitment. Inadequate spawning and rearing habitat, poor water quality, and entrainment all likely play a role in reducing productivity of White Sturgeon in this reach. White Sturgeon within Oxbow Reservoir will likely remain at extremely low abundance unless hatchery stocking occurs.

STOCKING

The Oxbow Dam to Brownlee Dam reach was stocked in the early 1990s. A total of 113 juvenile White Sturgeon were stocked in the reach between 1991 and 1994 (Table 4). Stocked individuals ranged in size from 33 to 40 cm FL. No recent hatchery stocking has occurred in the reach.

Table 4. Stocking data, mean fork length (cm), and number of hatchery White Sturgeon stocked in the Snake River between Brownlee and Oxbow dams, 1991-1994 (courtesy of Idaho Power Company).

Year	Date Stocked	Year Class	Age	Mean FL (cm)	River Mile	Number of fish
1991	14-May	1990	1	33	283.3	43
1994	14-May	1993	1	39	284.0	40
1994	12-Jun	1993	1	40	283.3	30
					Total	113

WATER QUALITY

Water quality impairment is considered a limiting factor in White Sturgeon abundance within the reach. Oxbow Reservoir is subject to poor water quality limitations which likely limit White Sturgeon production within the reach. During low flow years, Oxbow Reservoir experiences impaired water quality as a result of receiving anoxic water from Brownlee Reservoir (Meyer et al. 2001). Low dissolved oxygen levels lethal to White Sturgeon can compose up to 73% of the bottom 2-m layer in Oxbow Reservoir during low flow years (Lepla and Chandler 2001). White Sturgeon were documented in low numbers during the earliest creel surveys conducted in Oxbow Reservoir (Welsh and Reid 1971). Limited habitat is available for rearing White Sturgeon, specifically in summer. Oxbow Reservoir is listed as TMDL limited for nutrients, sediment, and pesticides (IDEQ 2004). Considering the current water quality conditions, the reach will be ranked as a lower priority for stocking.

FUTURE WORK

- Coordinate with Oregon Department of Fish and Wildlife to develop and implement a routine and standardized sampling design to increase understanding of White Sturgeon recruitment in the reach.
- Support IPC White Sturgeon population monitoring at 10-year intervals as indicated within the FERC License for Hells Canyon Dam. IDFG supports continued implementation of the IPC sampling rotation (once every 10 years) to maintain baseline data on White Sturgeon in the reach.
- Coordinate water quality monitoring with partner agencies within the reach to determine the efficacy of White Sturgeon stocking
- Work with partners to implement water management strategies which improve water quality and promote a White Sturgeon within the reach
- In years with high availability, stock reach in an experimental fashion to determine whether hatchery sturgeon remain in Oxbow Reservoir and increase reach abundance or entrain.
- Determine the optimal size for releasing hatchery sturgeon.
- Assess dam and turbine infrastructure to determine whether it is optimal to minimize entrainment or mortality. Seek modifications as necessary.

BROWNLEE DAM TO SWAN FALLS DAM

REACH METRICS

Management Designation: Stocked
Adult Population Abundance Objective: 2,900 adult fish >160 cm
Adult Population Estimate, Year: 193 fish >162 cm FL, 2019
Stocking Objective: 1,300 repatriated-origin/year, 30 cm / 200 g age-1, spring

REACH DESCRIPTION

This reach includes approximately 190 km of river habitat and 89 km of reservoir. The Snake River flows roughly 190 km below Swan Falls Dam before entering Brownlee Reservoir (Figure 16). Immediately downstream of Swan Falls Dam, the Snake River flows through a 22-km a basalt canyon section, confined by rock canyon walls, with relatively high gradient. Historically, this canyon likely provided the habitat characteristics, rock substrate and turbulent flows, necessary for sturgeon spawning and recruitment. As the river exits the canyon, it flows for the next 167 km through a broad unconfined valley bottom characterized by low gradient, a wide river channel, high width-depth ratio, and relatively few deep pools. Submerged aquatic macrophytes beds are common and riparian cover is limited. Major tributaries include the Owyhee, Boise, Weiser and Payette rivers, none of which provide sturgeon habitat. The downstream portion of this reach is impounded within Brownlee Reservoir. Completed in 1959 to provide flood control and hydroelectric power production, the reservoir covers a surface acreage of 5,908 hectares acres and is 89 km long at full pool. The fish community in this reach is extensively altered from the pre-European settlement and is comprised predominantly of non-native species. Common fish species throughout the reach include Smallmouth Bass, Channel Catfish, and Common Carp.

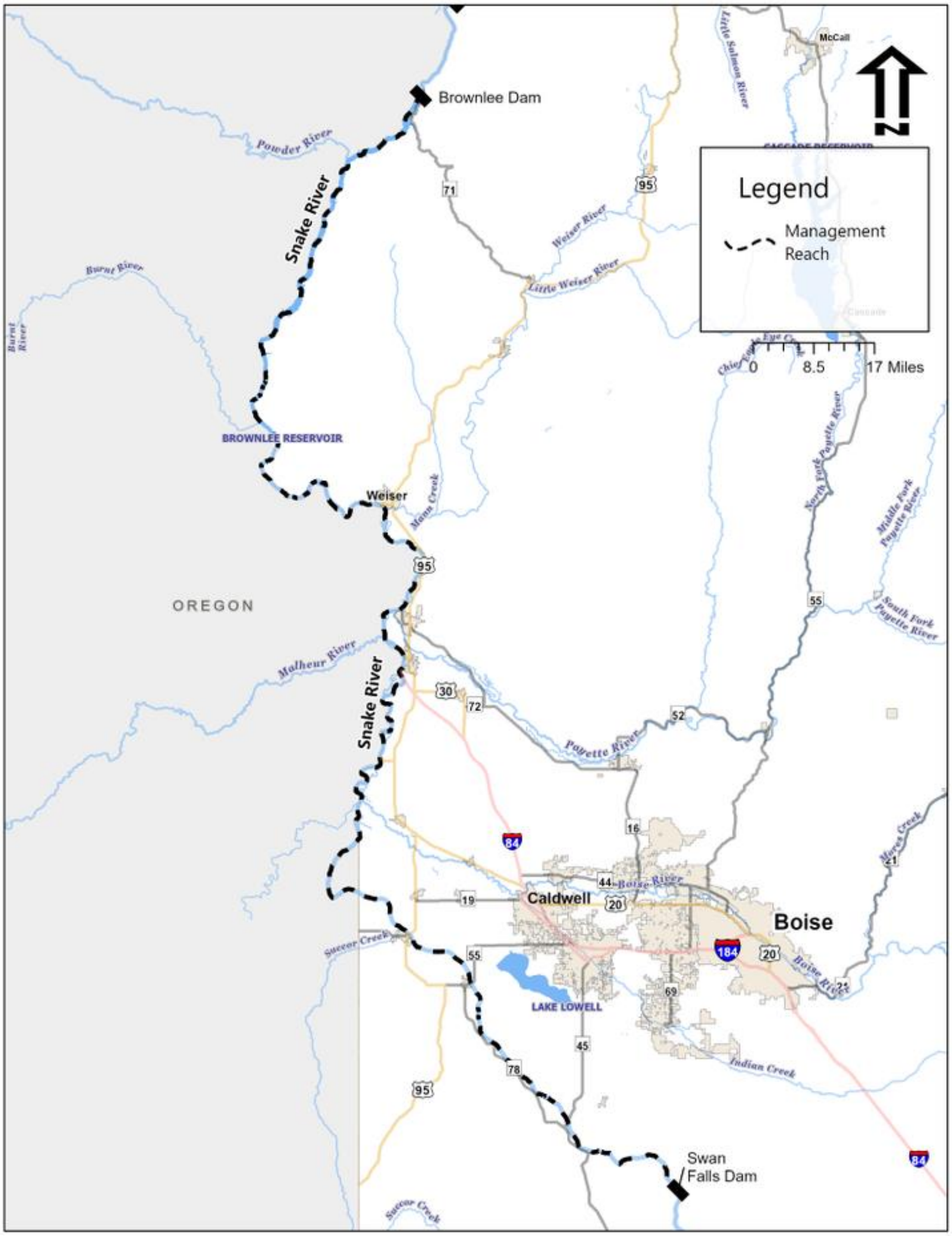

Figure 16. The Snake River from Brownlee Dam (downstream) to Swan Falls Dam (upstream).

Water quality in this reach has been severely impaired by nutrient loading from irrigation returns, and industrial and municipal sources (Harrison et al. 1999; Myers et al. 2002). The hydrograph is influenced by water storage and irrigation demands in the upper Snake River Basin.

As with the other facilities, the hydrograph is bimodal, and the high flows that trigger spawning may not coincide with suitable spawning temperatures.

POPULATION ASSESSMENTS

The sturgeon population has been studied by IDFG intermittently during the 1970s and 1980s with a variety of methods (Reid et al. 1973; Cochnauer et al. 1985; Reid and Mabbot 1987; Kruse-Malle 1993). While survey methods varied, catch rates were consistently low and most sturgeon were captured in the upper portion of the reach near Swan Falls Dam, suggesting low abundance throughout most of the reach.

In 1996-97, IPC completed the first population assessment in this reach (Lepla et al. 2001). The sampling design included random placement of setlines and utilized a mark-recapture approach. The total population (95% CI) greater than 90 cm TL was estimated as 155 (70-621) fish. The sample consisted primarily of larger and older individuals with few (4%) less than 80 cm TL (Figured SF2). The majority (75%) of sturgeon was captured in the narrow canyon section near Swan Falls Dam, while only 11 fish were sampled in Brownlee Reservoir (precluding a population estimate for the reservoir).

Similar surveys were completed in 2014 and 2019, with the intention of establishing a regular 5-year assessment interval. In 2019, the population was estimated (95% CI) at 312 sturgeon ≥ 60 cm (131-877). The vast majority (84%) of sturgeon were collected within 8 rkm of Swan Falls Dam, with 54% collected within only one mile. While the population point estimate of sturgeon was higher than in 2014 (N = 141), the population consisted of 46% hatchery-origin fish. As a result, the number of adult, wild-origin sturgeon remained similar to previous assessments, with approximately 150 wild-origin adults. Only two sturgeon were sampled in Brownlee Reservoir.

Size structure/growth

Past assessment data in 2014 indicated a size structure significantly shifted towards older, adult-sized fish (Figure 17). However, the size structure in 2019 reflected both aging natural-origin adults, as well as newly recruiting hatchery-origin juveniles, illustrating the continued lack of natural recruitment to this reach (Figure 18). Overall, the number of adult sturgeon has remained fairly constant around 150 individuals since 2014.

Growth rates of adult sturgeon in this reach average 0.4 cm/year, which is much slower than nearby upstream reaches (Bentz and Hughes 2020). The mean condition factor of adult sturgeon in the most recent 2019 assessment was 73, which has declined since 1996 assessment (82), and is noticeably lower than other nearby reaches such as C.J. Strike (84) or Bliss (86; Bentz and Hughes 2020). Bentz and Hughes (2020) found hatchery-origin juvenile sturgeon grew on average 5.5 cm/year, which was the slowest juvenile growth rate of any of the reaches upstream, which ranged from 6.3 to 11.7 cm/year.

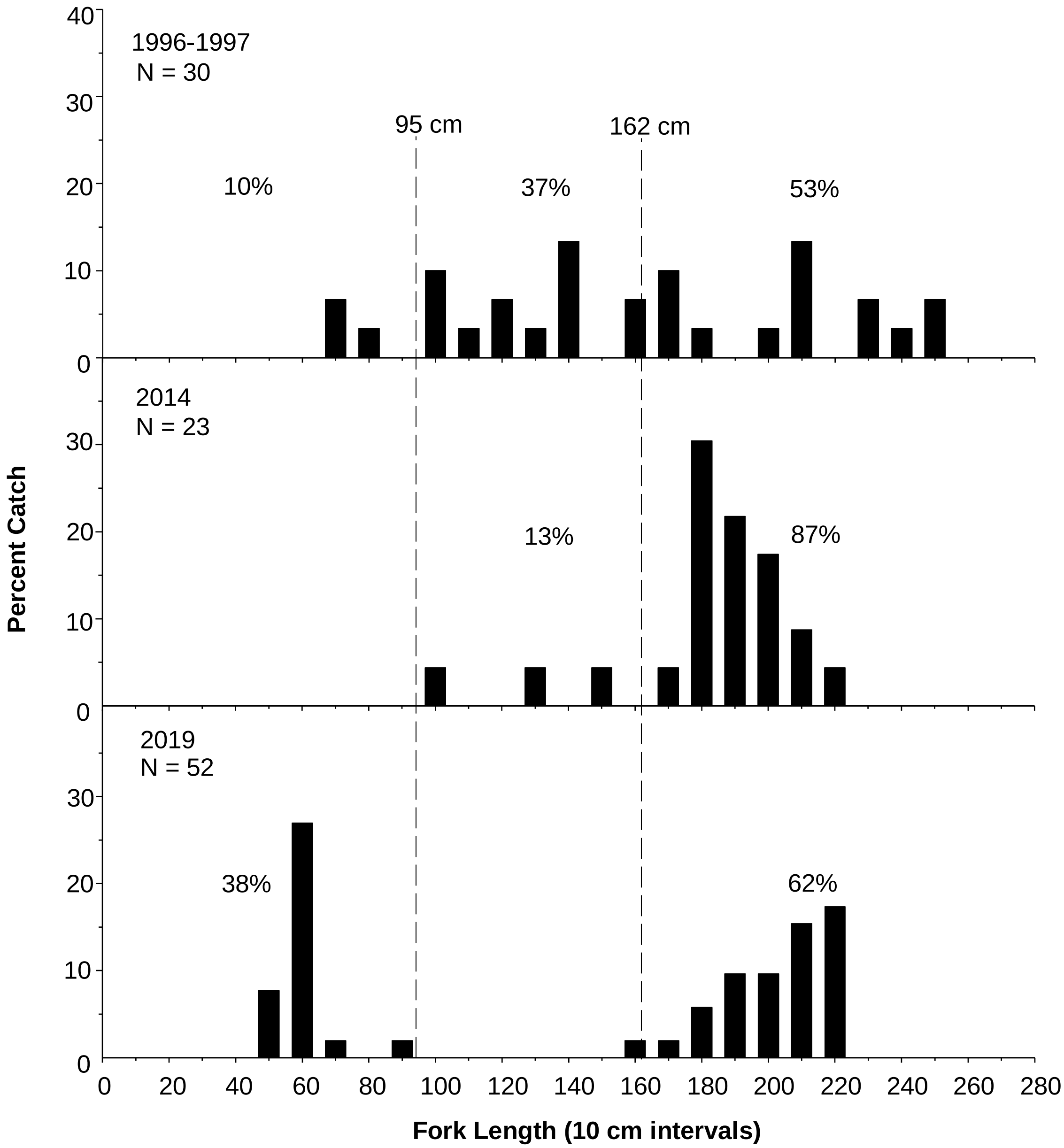

Figure 17. Length-frequency histogram of White Sturgeon sampled with setlines between Brownlee Dam and Swan Falls Dam by year (courtesy of Idaho Power Company).

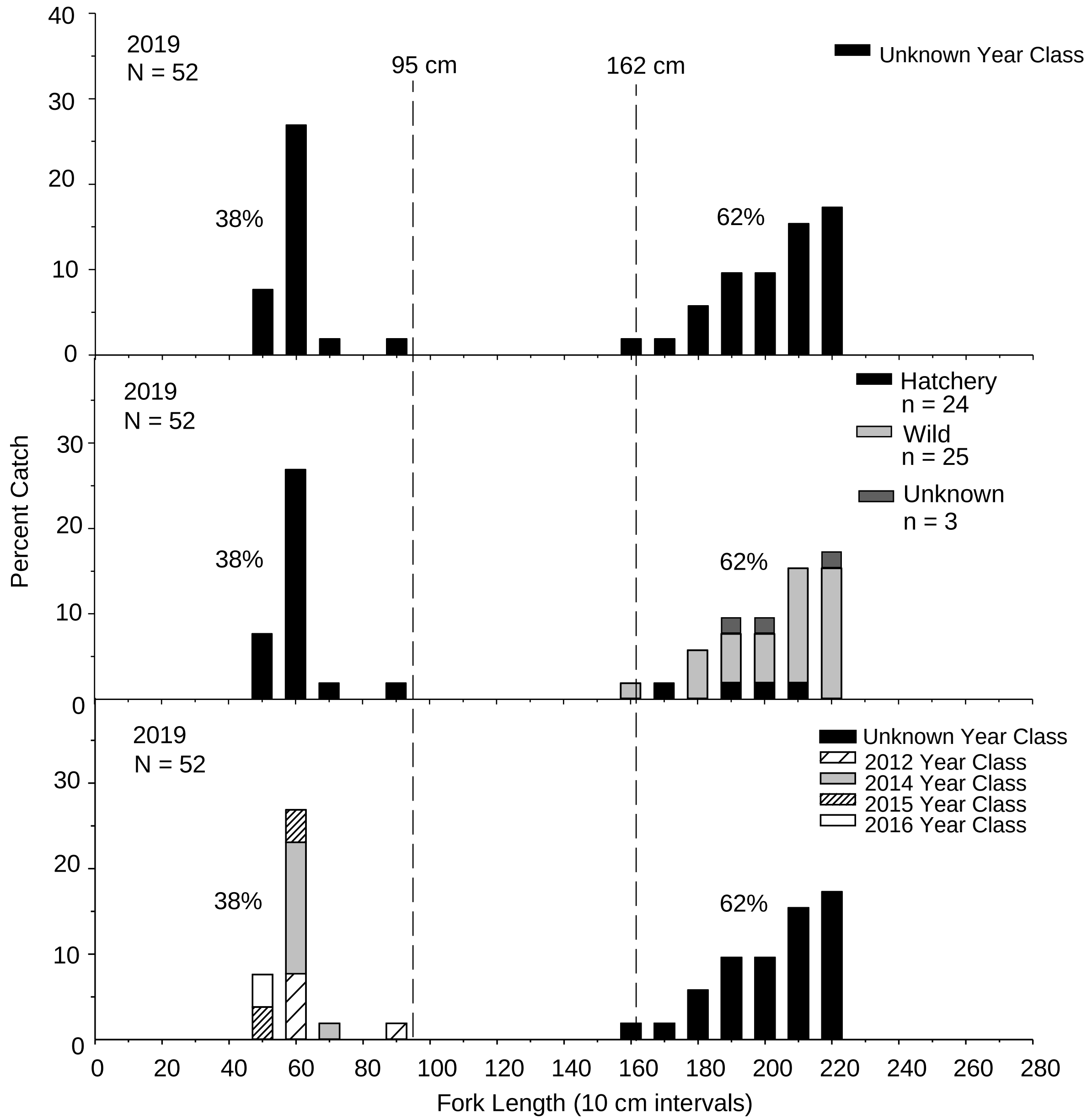

Figure 18. Length-frequency histogram of White Sturgeon sampled in 2019 with setlines between Brownlee Dam and Swan Falls Dam shown by origin and year class (courtesy of Idaho Power Company).

Survival

Compared to other mid-Snake River reaches and in general, survival across all life stages is lowest in this reach. The Swan Falls Reach has an overall mean annual White Sturgeon survival estimate of 0.75 across all size classes (95% CI, 0.73-0.77), with an adult survival rate of 0.93 (IPC, unpublished data). Juvenile and subadult survival are the drivers of this difference with considerably (10-20%) lower survival estimates in these life stages compared to upstream reaches. Adult sturgeon survival is estimated at 0.93 (95% CI, 0.88-0.95). Estimated adult sturgeon survival is second lowest compared to other mid-Snake River reaches (Appendix A).

Fishery monitoring

This reach supports a very popular White Sturgeon fishery, though formal data describing fishing effort is lacking. The river is easily accessible to both shoreline and boat anglers throughout this reach. Multiple highways and boat ramps provide angler access to much of the reach. Additionally, a road following the first 7 river km below Swan Falls Dam provides easy access to where the vast majority of sturgeon are located (84% of captures in the last assessment; Bentz and Hughes 2020). During the 2019 assessment, 33% of all fish scanned were positive for ingested metal (tackle). This rate increased slightly from 2014 assessment (26%), and the proportion of ingested metal was much higher for adults (43%) than for juveniles (10%). The high frequency of ingested tackle is likely indicative of intense angling effort in this easily accessible fishery. With a high overlap of anglers and sturgeon distribution, IDFG conservation officers have documented sturgeon poaching in this area, though the scale of the problem is unclear.

While this reach has several habitat and water quality challenges, the influence of angling, on slow growth, lower relative survival, poor W_r, and declining population trends should be investigated. A rigorous estimate of annual sturgeon angling effort in this reach is needed to inform management strategies for this fishery and assess potential effects of catch-and-release angling on the population.

RECRUITMENT AND JUVENILE MOVEMENT

The Swan Falls Reach has virtually no natural recruitment, with entrainment from upstream reaches providing limited contribution to this population. This trend is evident in the three population assessments from 1996 and 2014, for which size structure continued to shift towards adult size sturgeon, while juvenile and sub-adult fish were rare. The most recent 2019 assessment indicated the first appreciable numbers of juvenile sturgeon, which are exclusively a result of recent hatchery stocking efforts (Figure SF3).

In 2019, 35 individuals originating from the Bliss and C.J. Strike reaches were detected below Swan Falls Dam (Bentz and Hughes 2020). These were predominantly adult-sized wild-origin individuals but did include 12 hatchery-origin juveniles stocked in the C.J. Strike reach. This suggests downstream entrainment– especially during high water events such as 2017 – is likely supplementing this population. The consistent absence of any naturally-produced juvenile sturgeon may partly be a result of the low number of adult fish or the altered flow regime, but other factors such as water quality are likely contributing to the lack of successful spawning, incubation, and recruitment.

WATER QUALITY

Aquatic habitats in this reach have been extensively altered, primarily by agriculture and more recently by sub-urban and urban development, leading to reduced habitat quality for sturgeon. Water quality is generally poor in this reach due to excessive nutrient and sediment inputs from irrigation return flows. This portion of the Snake River is described as “not supporting coldwater aquatic life” beneficial uses of the Section 303 (d) of the Clean Water Act and has established TMDLs for multiple parameters. Depending on the section, these parameters include temperature, total phosphorous, DDD (dichlorodiphenyldichloroethane), DDE (dichlorodiphenyldichloroethylene), DDT (dichlorodiphenyltrichloroethane), dieldrin, and dissolved oxygen, sediment, mercury, pH (IDEQ 2003; IDEQ 2004; Gruen 2020). Data collected by IPC show summer daily maximum water temperatures average 23-24 ºC and can reach 27 ºC. Water temperatures above 25 ºC when combined with dissolved oxygen below 2-3 mg/L become lethal to sturgeon (see Figure 5 in Jager et al. 2001). Jager et al. (2001) concluded that poor water quality was the single most dominant factor controlling recruitment in this reach. In fact, their model predicted no recruitment even after removing all other potential controlling factors unless water quality also improved.

Extensive development of upstream reservoirs has significantly altered the hydrology of this reach by reducing discharge and altering timing of high-flow events. Reduced frequency of high flows in spring are thought have contributed to failed natural recruitment and likely exacerbate effects of high sediment loading on young sturgeon life stages, while lower year-round flows reduce the quality of sturgeon habitat in general. Channel dimensions (e.g. wide and shallow) also exacerbate already high summer water temperatures. Combined, these factors reduce and limit the availability of sturgeon rearing habitat and currently preclude natural recruitment.

Nutrient influxes from agricultural and municipal waste sources severely degrade water quality in the Snake River – and subsequently Brownlee Reservoir – during both normal and dry years (Jager et al. 2001). During low flow years, water quality in Brownlee Reservoir can become lethal to White Sturgeon, usually during mid to late summer. Lethal levels of low dissolved oxygen conditions can compose up to 80% of the bottom 2-m layer in the reservoir. In worst-case scenarios, the transition area at the upstream end of the pool can become anoxic throughout the water column (Lepla et al. 2001). In July 1990, lethal dissolved oxygen conditions (< 1 mg/l) combined with high water temperatures (25-26 ºC) caused the deaths of an observed 28 adult White Sturgeon in the upper end of Brownlee Reservoir (Grunder et al. 1993). All of these fish were greater than 115 cm TL, a reflection of the size structure in this reach. Modeling by Sullivan et al. (2003) predicted high sturgeon mortality when fish were unable to move to areas of less impaired water quality, which was likely the scenario during the 1990 fish kill. Furthermore, results from that study suggested reducing nutrient inputs in the Snake River could increase area of suitable sturgeon habitat in the reservoir and improve survival.

MANAGEMENT APPROACH

Stocking

The Brownlee Reservoir to Swan Falls dam reach is currently designated as a Stocked reach. IDFG considers this reach to be considerably below carrying capacity due to very low or no in-reach natural recruitment and minimal entrainment of juvenile sturgeon from upstream reaches. Subsequently, the reach has remained at very low densities, despite the relatively long segment of contiguous riverine habitat available. Furthermore, water quality improvements are likely to take decades more to implement and provide measurable benefits. Given these constraints, it is unlikely that the abundance of this is White Sturgeon population will increase due to natural recruitment for the foreseeable future.

Hatchery stocking began in 2010 and 2011 to increase sturgeon abundance in the reach. However, stocking didn’t occur annually until 2014. The number of hatchery-origin White Sturgeon stocked from 2014 to 2022 has varied between 95 and 1,302 annually. These adjustments reflect changes to stocking rates as more data on survival and population growth projections became available. Since 2014, there have been a total of 4,990 hatchery-origin fish stocked in the Swan Falls Reach, including 4,205 of repatriation origin. The current annual goal is 1,300 fish/year. According to modeling projections by IPC, this stocking rate would achieve the adult population target of 2,900 fish by about 2060 (Figure 19). However, based on low estimated survival of stocked juvenile sturgeon releases compared to other reaches, adjustment of current stocking objectives should be considered.

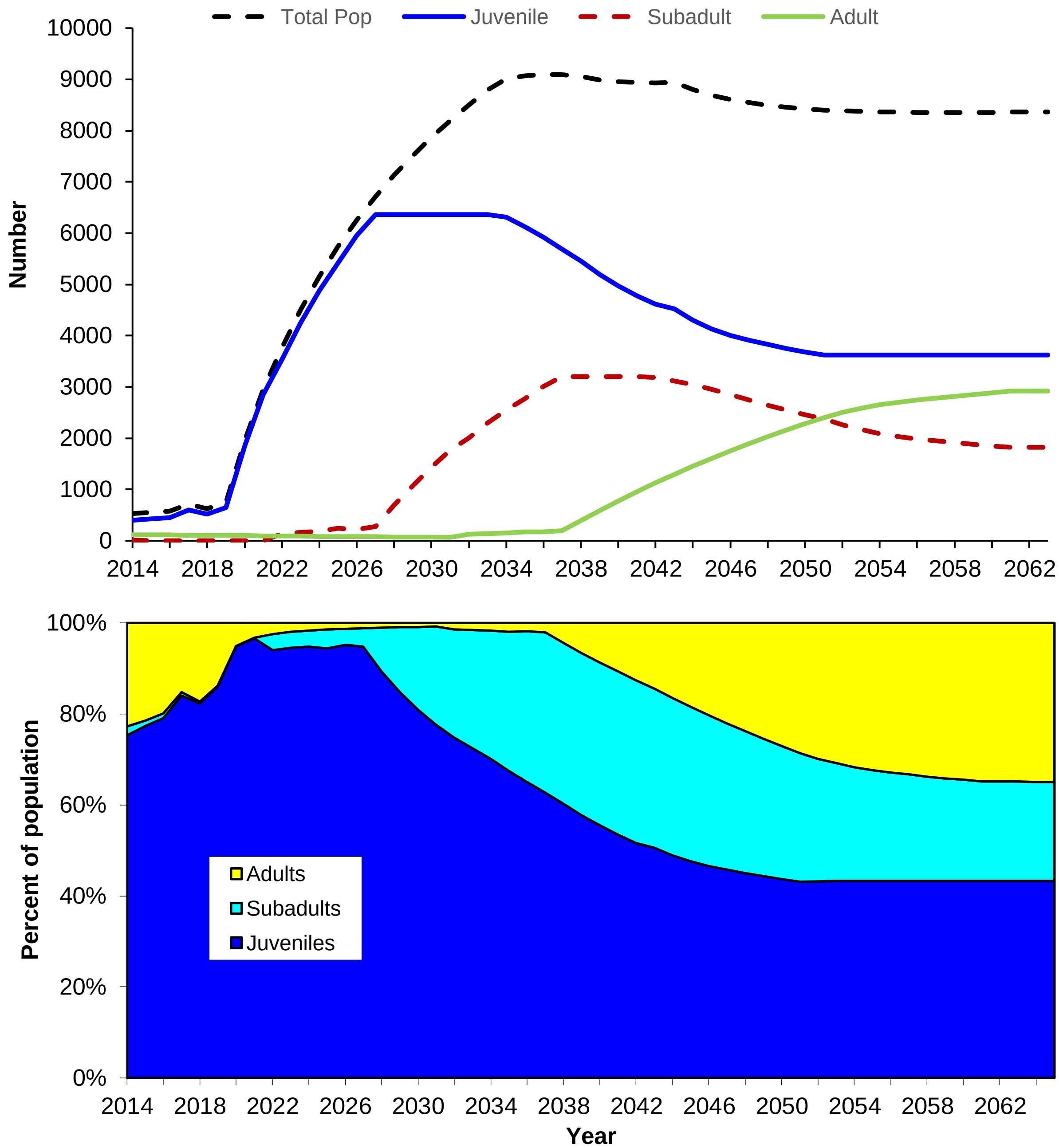

Figure 19. Model projections of White Sturgeon population from Brownlee Dam to Swan Falls Dam with annual stocking of 1,300 juveniles. (courtesy of Idaho Power Company)

FUTURE WORK

- Support IPC White Sturgeon population monitoring at 5-year intervals as indicated within the IPC White Sturgeon Conservation Plan.
- Evaluate survival of stocked hatchery sturgeon. Determine if a reduction of current stocking goal is warranted in the reach based on estimated juvenile survival.
- Seek solutions to improve water quality.
- Investigate potential factors contributing to low annual survival rates relative to other reaches.
- Estimate annual sturgeon angling effort and assess effects of catch-and-release angling on the population to inform management strategies
- Translocate any known origin C.J. Strike Dam to Bliss Dam fish collected in this reach back above C.J. Strike Dam.

SWAN FALLS DAM TO C.J. STRIKE DAM

REACH METRICS

Management Designation: Stocked
Adult Population Abundance Objective: 460 adults >160 cm (905 fish >60 cm)
Adult Population Estimate, Year: 103 fish >162cm FL, 2020
Stocking Objective: 320 fish/year, 30-40 cm yearlings, stocked in spring

REACH DESCRIPTION

The reach from Swan Falls Dam to C.J. Strike Dam includes 40 km of free-flowing river habitat, 17 km of reservoir, and approximately 42 km of sturgeon rearing habitat (Figure 20). C.J. Strike Dam was completed in 1950 and is 35 m high (115 ft), with a three-turbine powerhouse capable of passing a maximum of about 15,000 cfs through the powerhouse. Flows in excess of 15,000 cfs are passed over the spillway. Swan Falls Dam forms the downstream boundary of this reach, which is 27 m high (88 ft) and impounds approximately 17 km of reservoir with an average depth of approximately 2 m. White Sturgeon abundance in this section has declined as a result of several contributing factors including, very low recruitment (resulting from insufficient habitat to support spawning, and insufficient or infrequent high spring river flows, disrupted temperature regimes, poor water quality, and unexplained adult mortality (Idaho Power Company 2015; Jager et al. 2002; Kozfkay and Dillon 2011).

The river below C.J. Strike Dam is comprised mainly of low gradient shallow run habitat, as well as a few islands and deep pools. There are no rapids or narrow channels to create high-velocity zones and turbulent upwelling often associated with staging and spawning areas (Lepla and Chandler 2001). Only during median or high-water years is spawning habitat available and then only immediately below C.J. Strike Dam. There is no spawning habitat available at 5,000 – 10,000 cfs through the C.J. Strike Dam project (Lepla and Chandler 1997). Historically, it is unlikely White Sturgeon used this low-gradient section for spawning, but they may have reared in this section.

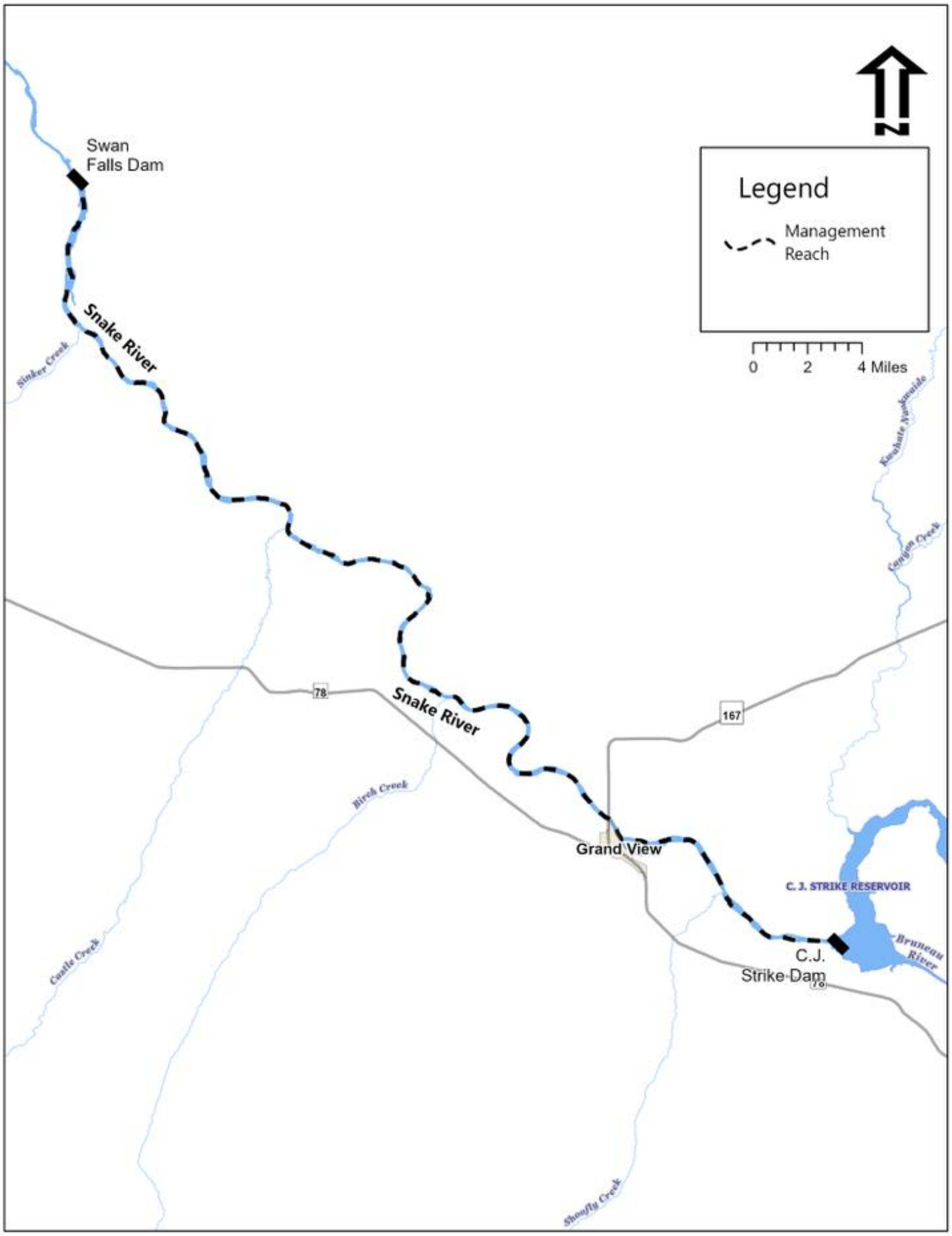

Figure 20. The Snake River from Swan Falls Dam (downstream) to C.J. Strike Dam (upstream).

POPULATION ASSESSMENTS

Abundance Estimates

The C.J. Strike Reach supports a small population of wild White Sturgeon, mostly comprised of adult fish. Population abundance has steadily decreased since as early as the 1970s (Cochnauer et al. 1985). The abundance of wild-origin fish has continued to decrease as a result of limited recruitment, poor water quality, higher-than-average mortality rates including unexplained mortalities, reduced entrainment from the Bliss Reach, and translocations. The number of adult-size sturgeon is projected to decline close to extirpation by around 2031, before the first hatchery-origin stocked fish will begin to recruit to adult sizes.

Since 1992, population assessments in this reach have been conducted approximately every five years. The most recent population estimate in 2020 was performed by IPC staff using a four-pass mark/recapture setline survey. The total White Sturgeon population (95% CI) was estimated at 240 (151-432) sturgeon ≥60 cm, or 0.43 fish/ha. This represents a 67% decrease since the highest estimate of 726 fish in 1995 (Figure 21). However, 41% of the estimated 2020 population was composed of hatchery-origin juveniles, suggesting the remaining wild population was around 142 fish (Figure 22), and that natural recruitment and entrainment still remains very limited or absent.

Translocation

Translocating reproductive adults between the C.J. Strike Reach and the Bliss Reach above has been ongoing since 2007. This program is intended to provide genetic and demographic benefits to these adjacent, but otherwise disconnected reaches. Between 2007 and 2022, there have been 130 adult sturgeon moved from the C.J. Strike Reach to the Bliss Reach. This total includes collecting adult brood stock for aquaculture purposes, which were subsequently returned to the Bliss Reach after being spawned. Translocation has likely contributed to the declining population trends, at least in some part, but does not account for the magnitude of declines since 2007. Additionally, translocation is accounted for in calculations of mean annual survival reported for this reach.

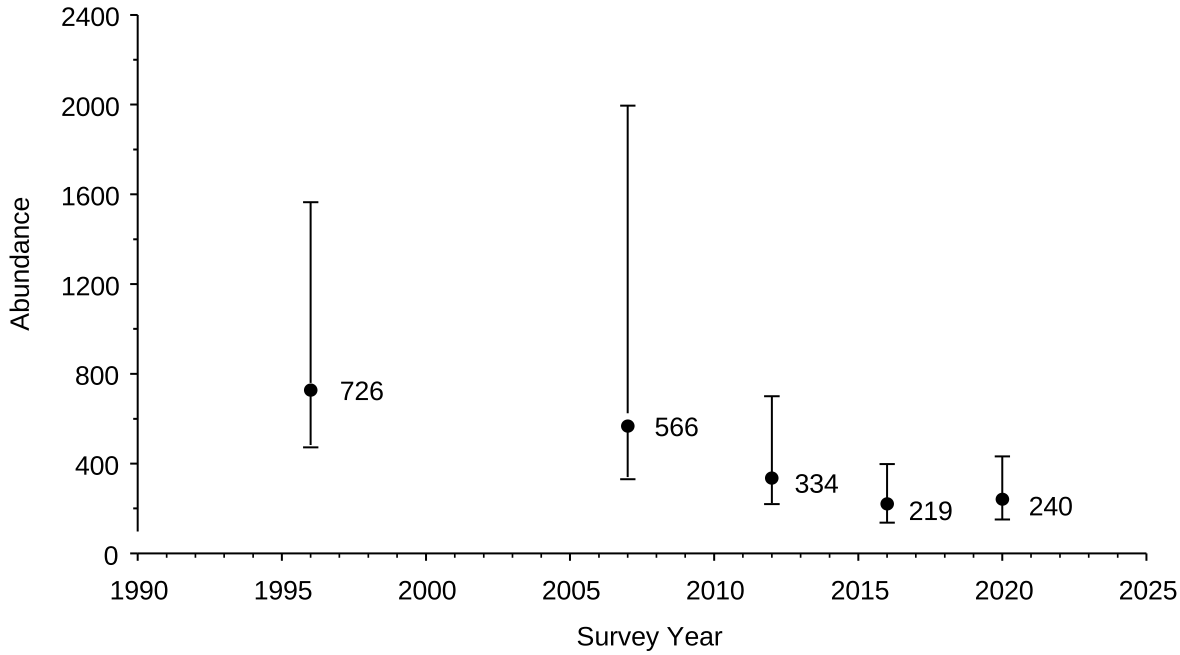

Figure 21. Mark-recapture population estimates (± 95% CI) of White Sturgeon in the Swan Falls Dam to C.J. Strike Dam reach by year (courtesy of Idaho Power Company).

Size Structure and Growth

Growth rates of White Sturgeon in the C.J. Strike Reach are relatively fast, being similar or slightly slower than those observed in the Bliss Reach, the fastest growth rate observed in Idaho reaches. Bentz (2018) used PIT-tag data from several years of surveys to estimate growth rates of three size categories of White Sturgeon. On average, mean annual growth for all size classes was 4.0 cm/year, based on the 2016 assessment. Growth rates for juveniles was 4.1 cm/year. Sub-adult and adults grew at 5.1 and 2.9 cm/year, respectively. However, more recent growth data for hatchery juvenile fish from the 2020 assessment suggested higher mean growth around 7.5 cm/year (Bentz and Hughes 2021).

The C.J. Strike Reach has virtually no natural recruitment, while entrainment over the dam provides only limited and inconsistent contributions to this population. This trend is evident in the five population assessments from 1992 to 2016, where size structure continued to shift towards adult size sturgeon, while juvenile and sub-adult fish were rare. Cochnauer (1983) suggested that the small population of White Sturgeon between C.J. Strike and Swan Falls dams was spawning-limited, as fish less than five years of age were not captured. In addition, the population may have been declining since the early 1970s (Cochnauer et al. 1985). During the sampling period 1986-1987 fish ranged from 100 to 180 cm TL. In 1989, anglers documented that 20% of the catch in this reach were small fish < 91 cm TL. In 1990, sport anglers caught an estimated 181 sturgeon with 18% < 92 cm, 64 % 92-183 cm, and 18% > 183 cm TL. However, in subsequent assessments from 1994 to 2016, fish < 92 cm continued to decline, and were virtually absent by the 2016 assessment. At that time, the population was comprised primarily of adult-sized fish (Bentz 2018b), with few juveniles present. The most recent 2020 population assessment indicated the first appreciable numbers of juvenile sturgeon, which are exclusively a result of hatchery stocking efforts beginning in 2014 (Figure 22).

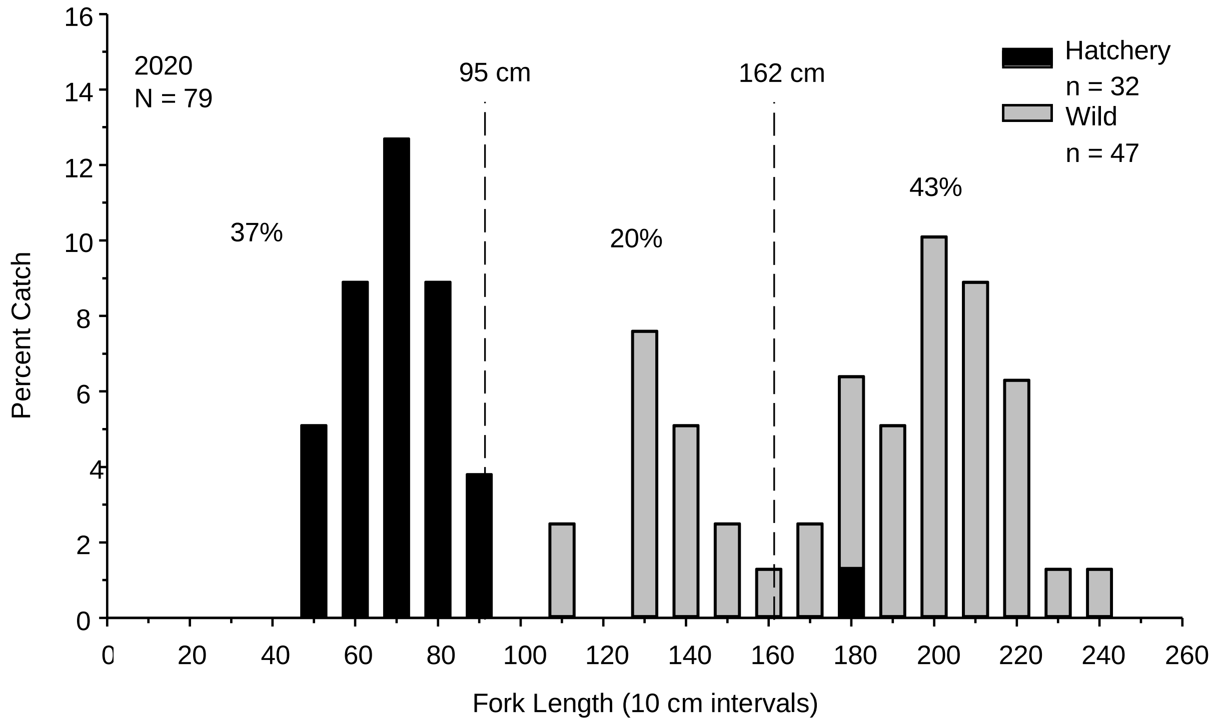

Figure 22. Length-frequency histogram of White Sturgeon sampled during 2020 from Swan Falls Dam to C.J. Strike Dam, collected with setlines (courtesy IPC). Hatchery fish are shown in black bars. (courtesy of Idaho Power Company)

Entrainment of mid-size and larger White Sturgeon from the C.J. Strike to Bliss reach was thought to be supporting this population. Data collected from PIT-tags supports this theory, and indicates some White Sturgeon do pass C.J. Strike Dam, mostly likely during high-water runoff events. Hughes (2019) estimated 100 to 150 sturgeon may have passed over the spillway in 2017 during the extended period of spill during this “wet’ year. However, data from PIT-tag recaptures also indicate these same events contribute to downstream emigration and entrainment into the Swan Falls Reach below, thereby reducing the net benefit of upstream subsidies. Whether fewer fish are entraining, or whether high-water events are occurring less frequently, entrainment over C.J. Strike Dam has not been sufficient to sustain this population, and abundance has continued to decrease. Following decades of prolonged recruitment failure and decreasing population trends, in 2014 IDFG initiated hatchery stocking to offset decreases in the C.J. Strike Reach.

Survival

The Swan Falls to C.J. Strike Reach has an overall mean annual White Sturgeon survival estimate of 0.90 (95% CI 0.89-0.91; IPC, unpublished data). Survival across all life stages is second lowest in this reach compared to other mid-Snake River reaches and in general, lowest mean annual survival estimates are in reaches below C.J. Strike Dam. Juvenile and subadult survival are 0.87 (95% CI 0.85-0.89) and 0.92 (95% CI 0.90-0.93) respectively. Adult sturgeon survival is estimated at 0.92 (95% CI 0.89-0.94). Estimated adult sturgeon survival is lowest in the Swan Falls to C.J. Strike reach.

Fishery monitoring

The tailrace immediately below C.J. Strike Dam is an intensively used White Sturgeon fishery. With good shoreline access and fish concentrated below the dam, anglers fish year-round and from spring through fall fishing effort occurs 24 hours a day. Kozfkay and Dillon (2011) performed a year-long White Sturgeon creel survey beginning in May 2007 and ending in April 2008 from C.J. Strike Dam downstream to the Grandview Bridge to quantify angling effort and describe the average frequency of hooking and landing for fish in this reach. Total annual fishing effort was estimated at 35,062 hours, with bank anglers accounting for 89% of the effort. White Sturgeon catch rates throughout the year were bimodal, with high catches in May and June, and again September – November. May and June accounted for nearly 50% of annual total catch, while few fish were caught through December, January and February. Using the 2005 population estimate (the most recent relative to this survey) of 566 individuals, Kozfkay and Dillon (2011) estimated that on average, White Sturgeon in this reach were hooked 7.4 times per year, including being landed 3.2 times and lost another 4.2 times per year. Retrospectively, these hooking and landing estimates were biased low as a subsequent population estimate indicated that abundance at the time of the creel survey had decreased further.

While the mortality rate per hooking encounter is not known, even relatively low mortality rates per encounter would be amplified by these high encounter rates and are likely one of the primary causes of this population's decline. Models produced by Jager et al. (2001) predicted that reducing angling mortality and larval export would provide the greatest benefit to increasing recruitment.

The proportion of fish with ingested metal in the C.J. Strike Reach has ranged from 27% (2020 assessment) to 54% (2011-2012), with adults having the highest rates at 42% (Bentz and Hughes 2021). When compared to six other nearby reaches in the Snake River, White Sturgeon in the C.J. Strike Reach had the highest proportion of ingested metal, especially in small (<92 cm TL) and medium (92 – 183 cm TL) size classes (IPC 2015; Appendix B). Rates of ingested tackle are much higher above the Grandview Bridge (34.1%) compared to those below the bridge (16.1%), which corresponds with the distribution of the majority of angling effort. High rates of ingested tackle are likely a sign of intense angling effort in this section and could be a contributing factor to the higher mortality rates observed in this population.

Mortality rates associated with catch-and-release angling on sturgeon populations are not well understood, especially in waters with reduced water quality. Given the high fishing effort in this reach and higher annual mortality rates compared to other reaches (see *Mortalities* section below), it is probable that fishing mortality is contributing to population decreases.

Mortalities

Mortalities of adult White Sturgeon have been monitored in this reach since 1994 and appear higher compared to other reaches. When possible, the carcasses have been retrieved by IDFG or IPC staff to determine the cause of death. Field necropsies and pathological examinations have not identified any consistent injuries or other factors associated with these mortalities the sources of mortality remain largely unknown. From 1994 to 2022, about 143 total adult sturgeon mortalities have been reported in this reach (IPC, unpublished data) and were classified as related to (1) the operation of C.J. Strike Dam (n = 26), (2) fishing tackle (n = 19), or (3) “unknown” (n = 98). Most mortalities have occurred during the spring spawning period, and most have been sexually mature or maturing fish. Given the spring timing, water quality was unlikely to be a factor contributing to observed mortalities. Examinations from histopathology and virology have not found abnormalities, and the effect of lingering legacy chemicals such as DDE, DDD, and PCBs is unknown.

Powerhouse-related mortalities continue to occur annually at C.J. Strike Dam, though records prior to 2004 are inconsistent. In 2000, IPC began using compressed air blasts prior to unit start-ups in an effort to “clear” White Sturgeon away from the turbine blades. Further modifications were completed in 2004 so that the turbine blades can be completely dewatered with compressed air prior to turbine start-ups. Data are inconclusive as to whether these procedures have reduced blade strike mortalities since implementation. Since 2004, there have been an average of 1.7 project-related mortalities per year. Acoustic monitoring studies have been ongoing for several years, and results indicate that very few sturgeon are passed through the powerhouse (Hughes 2019), suggesting mortality from entrainment through the powerhouse is very low.

Annual mortalities related to fishing tackle ingestion have averaged 1.7 mortalities per year since 2004. This is a minimum estimate and not corrected for detection efficiency. Fishing tackle is common in the stomach tracts of sturgeon collected during surveys in this reach. More information is needed on trends in fishing effort, and how catch-and-release fishing might be contributing to mortality and population abundance in this reach.

Mortality rates in the C.J. Strike Reach population of White sturgeon are significantly higher than most other reaches between Brownlee Reservoir and Shoshone Falls. Annual survival (± 95% CI) of all size-classes of sturgeon in the C.J. Strike Reach is estimated at 0.90 (± 0.01), while survival for adults-only is 0.92 (± 0.03) (IPC, *unpublished data*). For reference, the survival for all sizes and adults-only in the Bliss Reach upstream are estimated at 0.96 (± 0.02) and 0.98 (± 0.02), respectively.

This mortality has likely contributed to the population decreases in this reach and could affect the rate at which this population rebuilds following hatchery stocking. IDFG and IPC have established a contact list to report sturgeon mortalities in this and other river reaches and will continue efforts to identify and address the causative factor.

WATER QUALITY

Water quality in the C.J. Strike Reach is affected by several anthropogenic land uses and sources of pollution. Sources of pollution within the reach are associated with livestock grazing, irrigated agriculture, confined animal feeding operations, as well as from additional similar sources upstream of C.J. Strike Reservoir. As a result, water quality often becomes degraded as a result of excessive phosphorous, high temperatures, and low dissolved oxygen. While this section of the Snake River is designated to support coldwater aquatic life, the fish community is primarily warmwater and coolwater species (IDEQ 2022). The C.J. Strike Reach is listed on the Clean Water Act 303(d) list as “not supporting coldwater aquatic life” due to exceeding the coldwater maximum daily average temperature of 19ºC. Maximum temperatures in this section of river have exceeded 26ºC during periods of hot weather (IDEQ 2022). Dissolved oxygen levels in the tailrace of C.J. Strike Dam have been recorded as low as 5.1 mg/L; however, intervals of low dissolved oxygen are brief, usually lasting less than a week.

MANAGEMENT APPROACH

Stocking

White Sturgeon within the Swan Falls Dam to C.J. Strike Dam reach are currently designated as a Stocked Population. This section was previously considered a “Conservation Population” (IDFG 2008). However, natural recruitment and entrainment have remained very low, and the wild portion of the population has continued to decline. Without hatchery stocking, this population would likely be extirpated by 2040. In an effort to increase population abundance, hatchery stocking began in 2014. The number of hatchery-origin White Sturgeon stocked from 2014 to 2022 has averaged 149 fish/year, but has varied between 52 and 320 annually. These adjustments reflect changes to stocking rates as more data on survival and population growth projections became available. From 2014 to 2022, a total of 1,488 hatchery-origin have been stocked below C.J. Strike Dam, with 929 of those having been wild-caught natural eggs/larvae repatriated to this reach.

IDFG will continue to manage this population under the Stocked designation using conservation aquaculture techniques, using natural-origin eggs and larvae whenever possible. Currently, target stocking rates are for 320 juveniles per year, stocked in spring (Figure 23). Stocking rates should be evaluated as needed to account for changes in growth and survival to meet target population objectives.

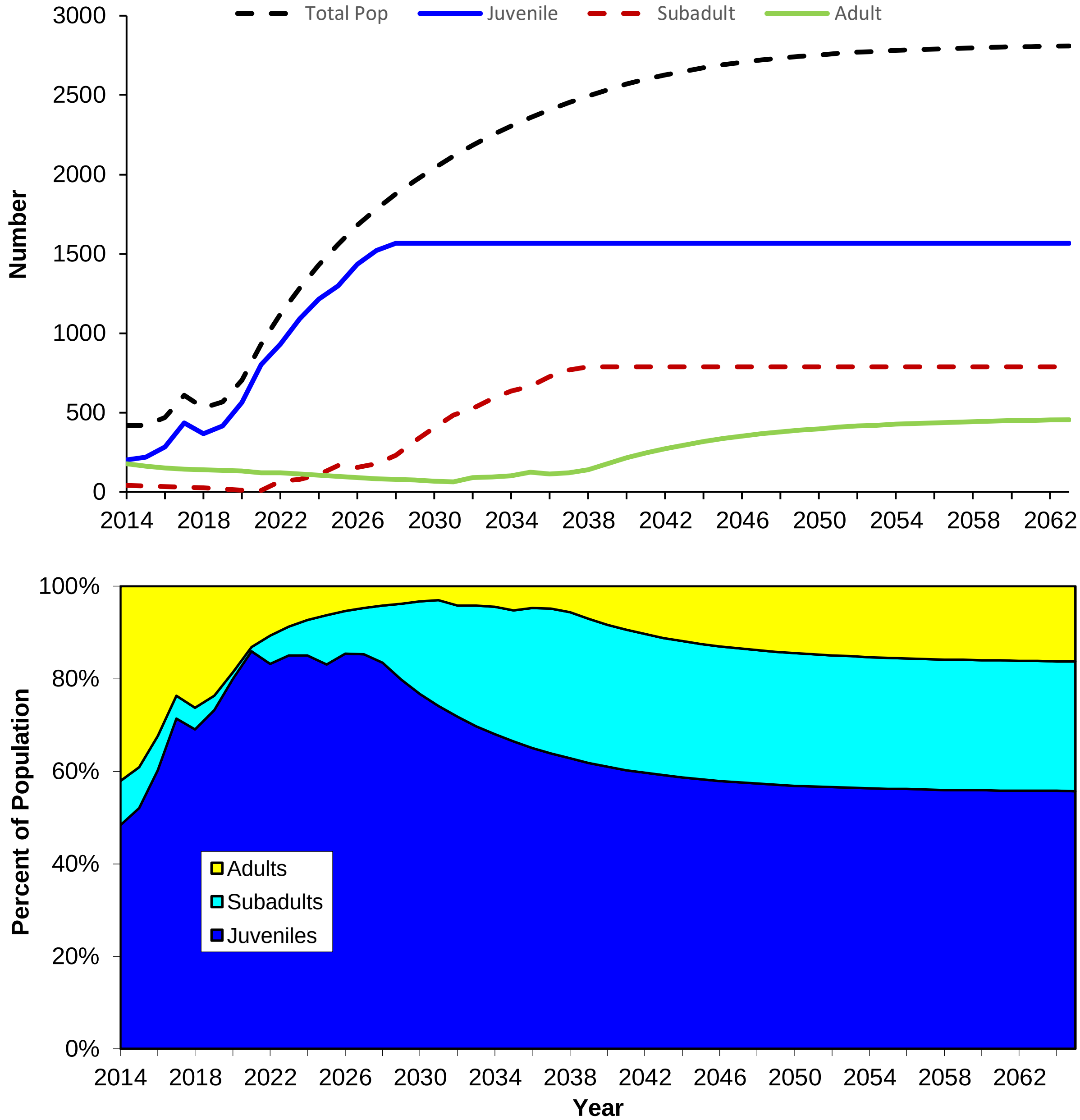

Figure 23. Model projections of White Sturgeon population from Swan Falls Dam to C.J. Strike Dam with annual stocking of 320 juveniles. (courtesy of Idaho Power Company)

Growth, condition and survival of stocked juvenile White Sturgeon suggest that stocking in the C.J. Strike Reach has been successful (Bentz and Hughes 2021). On average, juvenile sturgeon in this reach grow 7.5 cm FL/year, and those planted in spring tend to have faster annual growth rates than those stocked in fall. Survival of stocked juvenile sturgeon appears to be relatively high. Bentz and Hughes (2021) estimated first- and second-year survival of stocked juvenile sturgeon in this reach at 82% (95% CI 77.3-85.8). However, based on expected growth rates, it will be still decades before adult abundance of White Sturgeon begin to increase from current levels, reaching target objectives only after 2050 (Figure C.J.4).

Translocation

This population is supported primarily by downstream entrainment and does not appear to have adequate spawning and larval rearing habitat. As a result, reproductively mature fish have little chance to contribute to future populations. Translocating of a limited number of reproductive adults to the Bliss Reach directly upstream of C.J. Strike Reservoir could benefit both reaching through genetic exchange by natural spawning, and ultimately could provide demographic benefit to downstream reaches during emigration events (Jager et al. 2016). Additionally, continuing to translocate wild-origin reproductively mature to the Bliss Reach should improve individual survival rates. The total number of males or female White Sturgeon is to be coordinated with IPC staff annually. Effort should be focused primarily on moving F4-stage reproductive females, and secondarily on males. The IDFG will also consider whether to increase translocation efforts to move more wild-origin reproductive adults to the Bliss Reach as hatchery-origin fish begin to recruit to the fishery.

FUTURE WORK

- Support IPC White Sturgeon population monitoring at 5-year intervals as indicated within the IPC White Sturgeon Conservation Plan.
- Continue adult translocations – coordinate annual objectives for males/females. Consider increasing translocation rates of wild-origin adults as hatchery fish begin to recruit to the fishery.
- Stock 320 juvenile White Sturgeon annually using natural-origin eggs/larvae through conservation aquaculture. Adjust stocking rates as needed based on survival rates.
- Investigate potential factors contributing to low annual survival rates relative to other reaches.
- Evaluate survival of stocked hatchery sturgeon.
- Estimate annual angler effort periodically.
- Assess effects of catch-and-release angling on the population and evaluate regulation changes if needed.
- Assess effects of water quality impairment which may affect sturgeon population abundance.

C.J. STRIKE DAM TO BLISS DAM

REACH METRICS

Management Designation: Core Wild
Adult Population Abundance Objective: 2,065 fish >162 cm FL (includes river and reservoir habitat)
Adult Population Estimate- 1,928 fish >162 cm FL, 2021
Stocking Objective: None, abundance sustained through wild recruitment

REACH DESCRIPTION

The reach between C.J. Strike Dam and Bliss Dam (The Bliss Reach) has approximately 145 km of habitat, with 106.7 km of free-flowing river and 38 km of reservoir (Figure 24). The reach includes over 16 km of flowing river in the canyon area from Bliss Dam to Clover Creek, located near the community of King Hill. The river falls about 1 m/km through this canyon reach. It is typically fast, deep (>10 m) run-type habitat with intermittent pools and riffles with several pools up to 15 m deep. For about 53 km below Clover Creek, the river flows through relatively flat terrain with lower gradient (0.6 m/km) down to the C.J. Strike Reservoir pool. The run-type habitats in this reach support abundant aquatic vegetation in the summer. There are a few pools 8-10 m deep and one pool over 20 m deep. Water temperatures within the reach vary from 7 to 25°C.

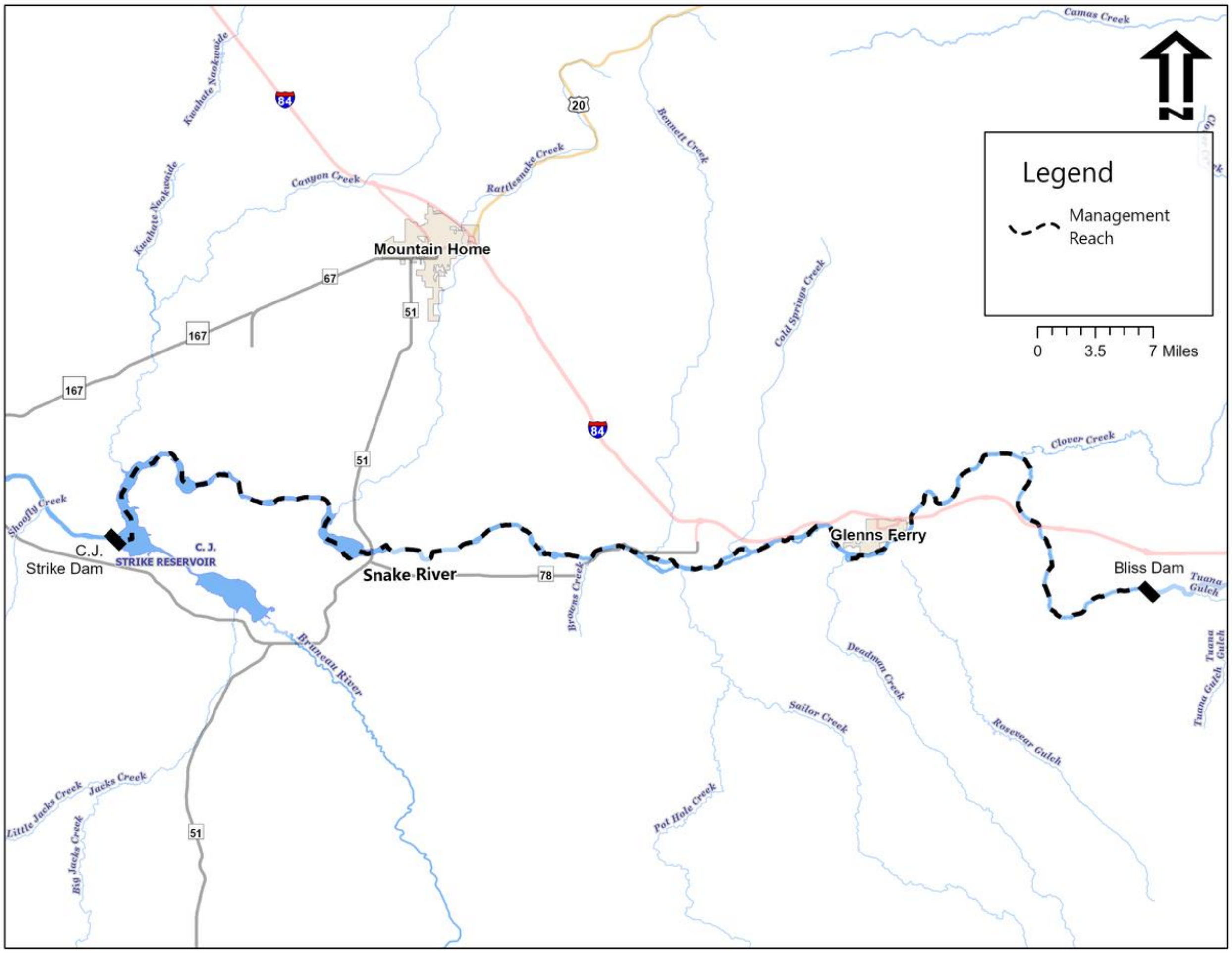

Figure 24. The C.J. Strike Dam (downstream) to Bliss Dam (upstream) reach of the Snake River, Idaho.

POPULATION ASSESSMENTS

Current population monitoring metrics include abundance, density, biomass, size structure, condition factor, growth rates, and apparent survival. Idaho Power Company currently conducts population assessments approximately every five years in association with their FERC-license requirements.

Population Estimate

Point estimates from the last several surveys suggest the Bliss Reach population has mostly expanded since the early 1990s (Figure 25.; Bentz and Hughes 2022). However, point estimates from the most recent survey in 2021 indicate a slight decline since the high of 2015, though confidence intervals are overlapping with previous estimates. The number of fish greater than 162 cm has increased by 14% since 2015 and suggests the population is getting older and larger over time.

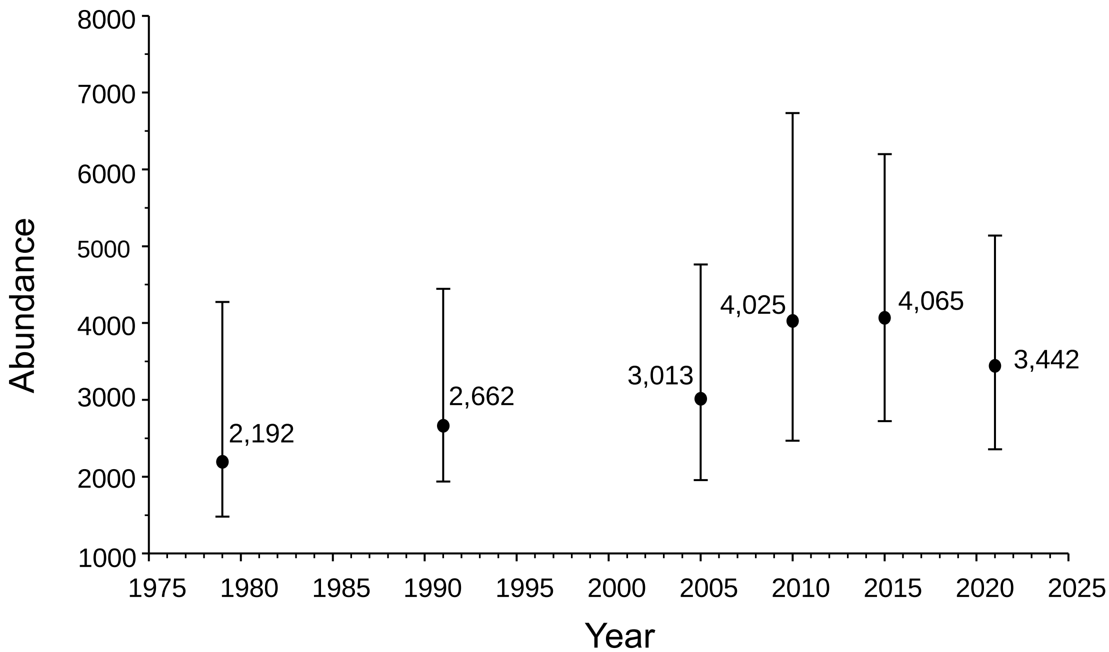

Figure 25. Abundance estimates for White Sturgeon (>60 cm FL) from C.J. Strike Dam to Bliss Dam, 1979-2021 (courtesy of Idaho Power Company).

The reach contains one of two remaining populations of White Sturgeon supported by natural recruitment in Idaho and continues to maintain high reproductive potential. IPC has conducted White Sturgeon recruitment monitoring since 2006, to quantify year class strength, apparent survival, and growth rates (Bates 2022). Apparent survival was relatively high across all size groups (averaged 96%) and ranged from 94% (juveniles) to 98% (adults; Bentz and Hughes 2022). It appears that natural spawning events occur each year; however, larval production and subsequent recruitment of juveniles to the population is highly variable. Previous studies have identified natural recruitment as generally limited or absent in low to normal water years (Brink and Chandler 2000), while more recent studies have identified a strong correlation between flow and recruitment (Bentz and Hughes 2022). Current data suggests that flows in excess of 16,000 cfs are likely needed to generate measurable White Sturgeon recruitment within the reach (Bates 2022). Achieving these flow conditions periodically will be important to maintaining the natural reproductive success of this population.

Size Structure and Growth

Past assessments document regular recruitment and relatively stable size structure in the reach (Figure 26). Growth rates and relative weights documented in the reach illustrate fast growth rates (IPC 2015). Juvenile growth rates documented within the reach represent some of the highest in the species range (Bates et al. 2014). This productivity results in earlier maturation compared to downstream reaches such as Hells Canyon and some females reaching maturity by age 17 to 18 (Bentz and Lepla 2009).

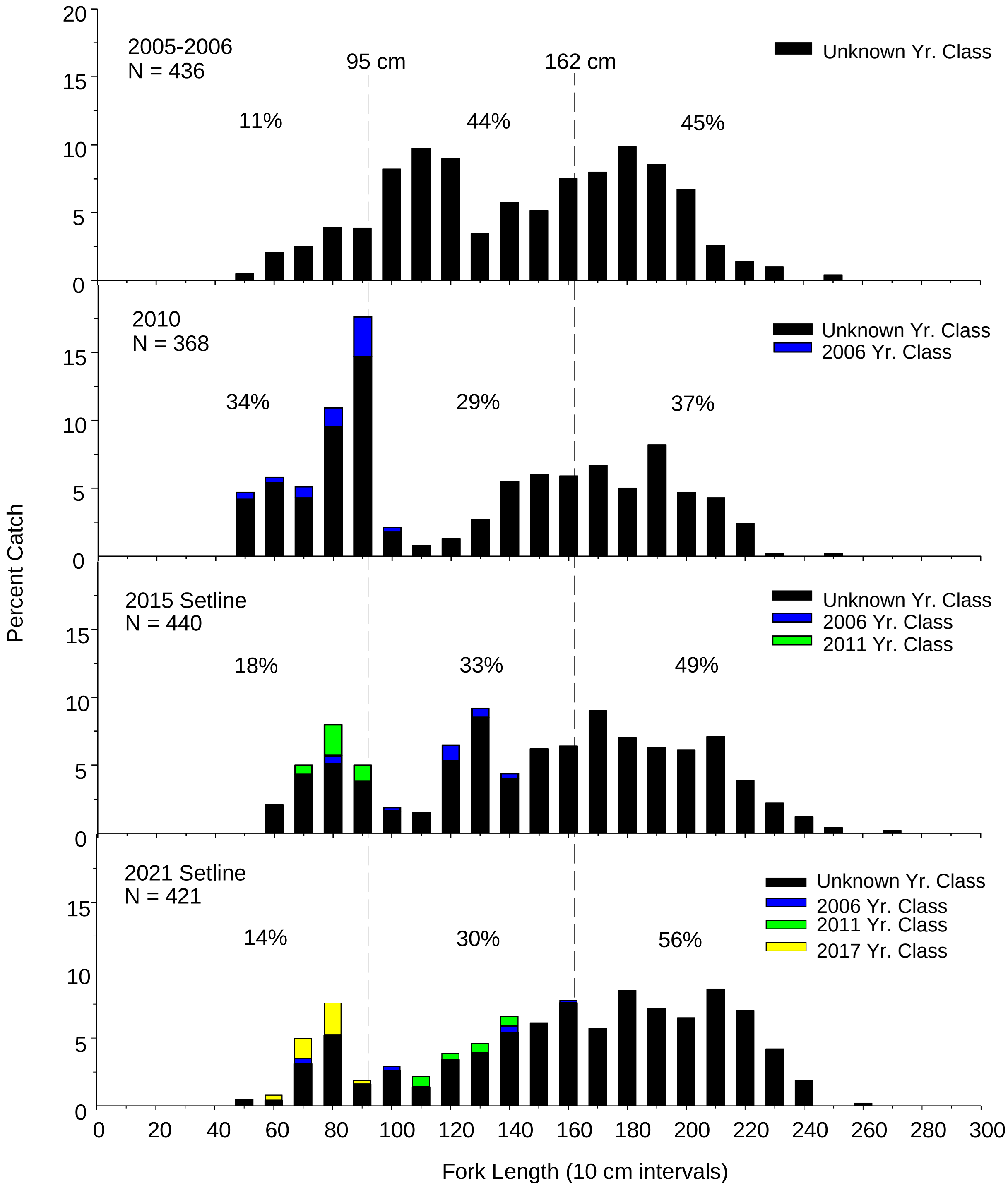

Figure 26. Size structure of White Sturgeon sampled in the C.J. Strike Dam to Bliss Dam reach of the Snake River, Idaho during assessment years 2005-2006, 2010, 2015, and 2021 (courtesy of Idaho Power Company).

During the 2021 assessment, condition factor (W_r) was estimated at 87, which was the lowest observed, across all habitat types, since the metric was first measured in 2005 (Bentz and Hughes 2022). Growth rates within the Bliss reach vary widely, with growth rates generally following a longitudinal gradient. Growth is slowest in the upper riverine portions (3.3 cm/year) and fastest in the reservoir (6.7 cm/year), with an overall average of 5.7 cm/year across the reach (Bentz and Hughes 2022). Overall, the population exhibits fast growth rates when compared to other populations within native reaches of the Snake River. Bates et al. (2014) used extensive mark-recapture metrics and found the Bliss reach population to have an intrinsic rate of increase in growth of ($K = 0.118$) nearly double that of the Hells Canyon reach ($K = 0.059$), primarily because of differences in growth rates of juvenile fish ≤120 cm, while adults actually grew at similar rates. As a result, juvenile White Sturgeon in the Bliss reach are reaching adult sizes (and maturity) more rapidly.

Survival

The mean annual White Sturgeon survival rate in the Bliss reach is 0.96 (95% CI 0.94-0.97; Bentz and Hughes 2022). Survival across all life stages is highest in this reach compared to other mid-Snake River reaches (Appendix A). Juvenile and subadult survival are 0.94 (0.92-0.95) and 0.95 (0.93-0.96), respectively. Adult sturgeon survival is estimated at 0.98 (0.96-0.99). Estimated adult sturgeon survival is highest in the Bliss reach, but overall comparable to other mid-Snake River reaches above C.J. Strike Dam.

Entrainment at C.J. Strike Dam

White Sturgeon population assessments below C.J. Strike Dam have documented entrainment of Bliss Reach fish downstream through the dam. However, limited information was available to assess the rate of entrainment and any potential mortality associated with passage through dam turbines. IPC monitored the C.J. Strike Dam forebay and penstocks during the spring season during multiple flow conditions from 2007 to 2016. This study found entrainment through the dam is rare and does not constitute a biologically significant effect on the White Sturgeon population in the reach (Hughes 2019). Passage over the dam through the spillway during high water events appears to be a more significant source of entrainment. High runoff conditions in 2017 resulted in prolonged spill at C.J. Strike Dam, and IPC biologists estimated that 100 – 150 White Sturgeon passed the dam that spring (Hughes 2019). White Sturgeon entrained from the Bliss Reach may occur farther downstream. While surveying the Swan Falls reach during 2019, IPC biologists collected four sturgeon previously marked in the Bliss Reach that entrained through both C.J. Strike and Swan Falls dams (Bentz and Hughes 2020a).

Fishery monitoring

The limited creel data available for the C.J. Strike Dam to Bliss Dam reach was collected by IPC during 2007-2009. Compared to overall angling effort in C.J. Strike Reservoir, angling specifically targeting White Sturgeon was low relative to those targeting bass and panfish. On average, 3.1% of interviewed anglers were targeting White Sturgeon (Brown et al. 2010). However, these anglers were exclusively fishing in the reservoir pool, and no quantitative estimates of angler effort in the riverine portion are available. Observations of dead adult White Sturgeon in the reservoir pool in late summer during 2022 raised concerns that recreational angling during low dissolved oxygen and high-water temperature periods may be causing or exacerbating mortality. Little data is available to evaluate this potential concern and additional investigations of angling effort and its potential effects on White Sturgeon mortality (especially during stressful periods of poor water quality) within the fishery are needed.

The prevalence of ingested metal within White Sturgeon in the Bliss Reach varies by fish size and location and may be a surrogate for the intensity of angling by location. During the 2021 population survey, the mean population rate of ingested metal across all habitats and sizes was only 11.1% (n = 405; Bentz and Hughes 2022). Ingested metal was much more prevalent in adult sizes, with 9.6% of adult White Sturgeon having ingested metal in the reservoir (n = 191), compared to 27% (n = 62) of adults in the upper riverine portion near Bliss Dam. This is a consistent trend since in prior surveys in 2015 and 2010 (Bentz and Hughes 2022) and suggests that the intensity of angling effort is much greater in the riverine portion, especially in the tailrace fishery below Bliss Dam. A robust sport fishery exists throughout the Bliss reach and coincides with the timing of both spawning-related migrations and spawning activity. IDFG will manage the Bliss reach population to conserve genetic diversity and natural recruitment. Future work should include a robust assessment of angling effort in this reach, and whether catch-and-release angling is appropriate during the spawning period of this naturally reproducing population.

WATER QUALITY

Spring inputs from the Thousand Springs area in the reach above likely temper winter minimum temperatures and provide some flow and water quality mitigation during summer months. However, water temperatures (King Hill gauge) are often consistently above 19°C for much of July and August and regularly hit 22°C. Recent observations of adult White Sturgeon mortality in the reservoir section of the reach have been linked to water quality impairment, specifically temperature and low dissolved oxygen in the reservoir. Twenty adult White Sturgeon mortalities were documented upstream of C.J. Strike Dam during late summer 2022. This is a minimum estimate that was not corrected for detection efficiency. These mortalities were related to areas of C.J. Strike Reservoir which contained dissolved oxygen and water temperatures near or at levels lethal to White Sturgeon. In addition, angling effort was occurring at the same time. It is unclear whether water quality impairment or stress associated with angling, or a combination of the two was the ultimate cause of mortality. Regardless, IDFG determined the risk and potential impact to the population of White Sturgeon within the reach warranted a emergency fishery closure. This water quality- or fishing-related closure was the first of its kind issued by IDFG. IDFG is committed to future monitoring and research to understand the severity of the water quality issues and determine if further management action is warranted.

MANAGEMENT APPROACH

The C.J. Strike Dam to Bliss Dam reach supports the most robust population of White Sturgeon in the middle Snake River (Bates et al. 2014). The population is characterized by high growth rates, maintains high genetic diversity, and stable abundance trends over the past 20 years (IPC 2015). This reach will continue to be managed as the only Core Wild reach in the middle Snake River with no stocking of hatchery fish. Development of the repatriation program which uses wild spawned and subsequently reared progeny has reduced the threat of hatchery fish entering the reach having negative effects on genetic composition of wild fish in the reach. However, historical stocking and unintentional releases of hatchery sturgeon from upstream commercial aquaculture facilities still pose a risk to wild fish genetics. IDFG recommends continued monitoring for unintentional hatchery introductions into the reach and culling of individuals which were not part of the repatriation program. Hatchery sturgeon from commercial aquaculture or hatchery supplementation efforts prior to initiation of the repatriation program will be removed from the population when collected during monitoring efforts.

Although the C.J. Strike Dam to Bliss Dam reach has stable population trends recruitment in the reach appears inconsistent. Recruitment of White Sturgeon in the reach has been linked to river flows during spring spawning. Recruitment years have been associated with river flows exceeding 16,000 cfs and strongest recruitment years (2006, 2011, and 2017) were associated with river flows exceeding 25,000 cfs (Bentz and Hughes 2022). Maintaining spring river flows in exceedance of these triggers is important for maintaining regular recruitment events in the reach. Recruitment events in the C.J. Strike Dam to Bliss Dam reach are important for maintenance of the population within the reach and the repatriation aquaculture program which supplements other reaches in the middle Snake River.

FUTURE WORK

- Support IPC White Sturgeon population monitoring at 5-year intervals as indicated within the IPC White Sturgeon Conservation Plan.
- Evaluate entrainment rates into and out of this reach.
- Maintain sturgeon recruitment monitoring to inform management decisions surrounding the repatriation program and stocking release objectives.
- Continue to translocate adult White Sturgeon from downstream reaches to increase spawning potential and genetic diversity.
- Collect creel data to estimate angler effort and catch.
- Complete research to determine the frequency and ultimate cause of summer White Sturgeon mortalities. Address the ultimate cause.
- Generate a minimum abundance objective to maintain broodstock for repatriation program and develop management tools to address recruitment if population drops below objective.
- Adjust fishing regulations if needed to protect spawning adults, maintain genetic diversity and natural recruitment
- Collaborate with water managers to achieve spawning flows (>17,000 cfs) to maintain natural recruitment in the reach.

BLISS DAM TO LOWER SALMON FALLS DAM

REACH METRICS

Management Designation: Stocked
Adult Population Abundance Objective: 110 fish >162 cm FL
Adult Population Estimate, Year: 55 fish >162 cm FL, 2022
Stocking Objective: 50 juveniles per year

REACH DESCRIPTION

The Snake River between Lower Salmon Falls Dam and Bliss Dam consists of 13 km of free-flowing river and 8 km of reservoir habitat (Figure 27). The river canyon is narrow with bedrock and rubble lining the deep pools and rapids. The Malad River, formed by the confluence of the Big and Little Wood rivers, enters in this section. Below Lower Salmon Falls Dam, the river is free-flowing with relatively high gradient (~2%) and provides White Sturgeon spawning habitat even at the lowest flows (Cochnauer 1983). However, since the riverine section of the reach is short compared to reaches with documented natural recruitment, any naturally produced larvae are likely entrained downstream and lost to the population. Bliss Dam, constructed in 1950 at the site of a natural falls, impounds the lower 8 km of the reach.

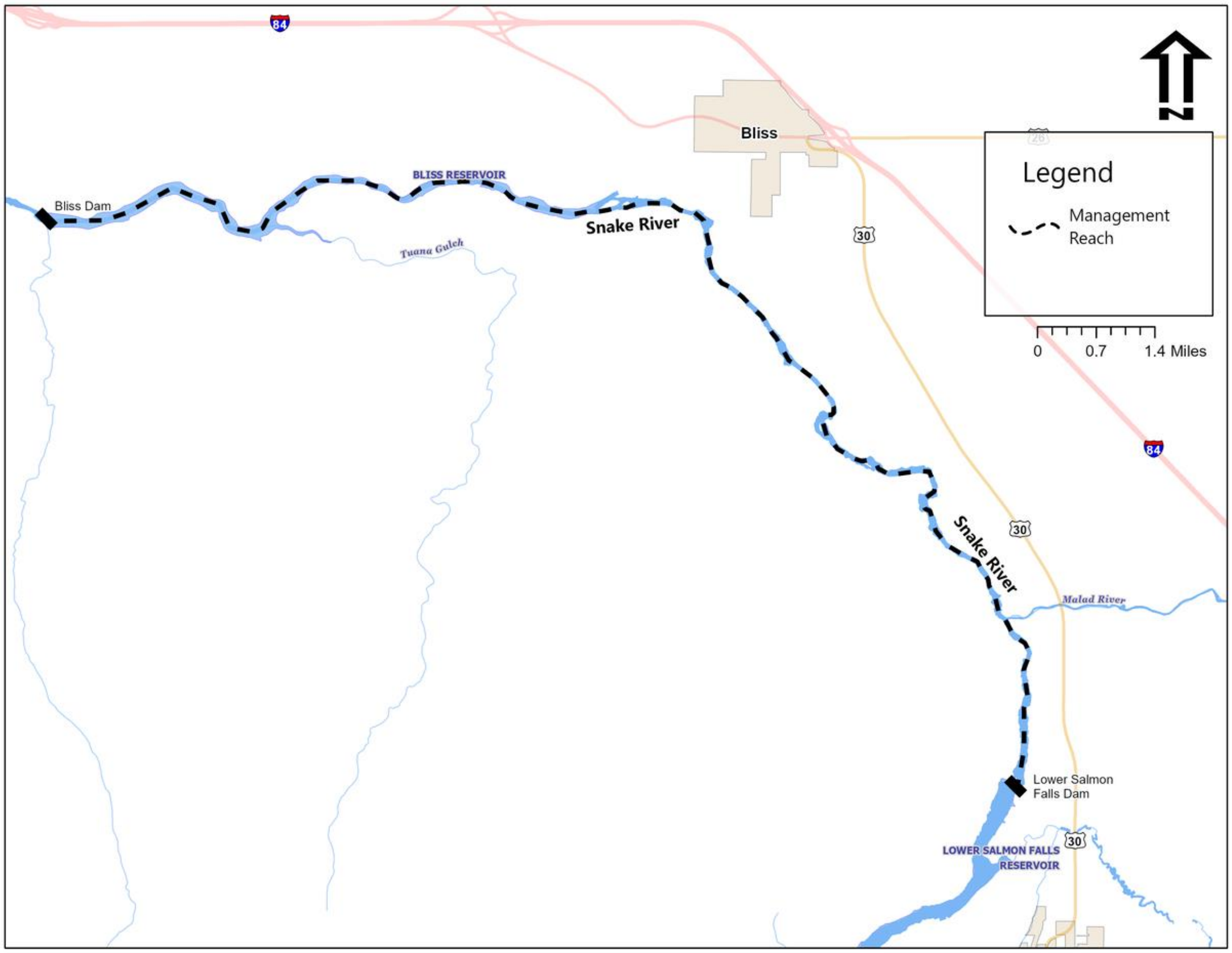

Figure 27. The Bliss Dam (downstream) to Lower Salmon Falls Dam (upstream) reach of the Snake River, Idaho.

POPULATIONS ASSESSMENTS

Current population monitoring metrics include abundance, density, biomass, size structure, condition factor, growth rates, and apparent survival. Idaho Power Company conducts population assessments approximately every five years in association with their FERC-license requirements.

Abundance Estimates

White Sturgeon abundance between Bliss and Lower Salmon Falls dams. Lukens (1981) reported capturing 11 wild sturgeon in the Lower Salmon Falls tailrace with little evidence of recent recruitment. Hatchery stocking was initiated in 1989 to increase abundance and maintain sport fishing opportunity. The 2022 population abundance estimate was 99 sturgeon (>60 cm FL) and has remained relatively stable since 2004 (Figure 28). White Sturgeon densities have ranged from 3 to 5 sturgeon/km within this reach (Bentz and Hughes 2019). The adult abundance objective for the reach is 110 fish >162 cm FL, which is 2.2-fold higher than the current estimate of 50 adults. Mean relative weight of sampled sturgeon was 82 and stable compared to past assessments (Bentz and Hughes 2019).

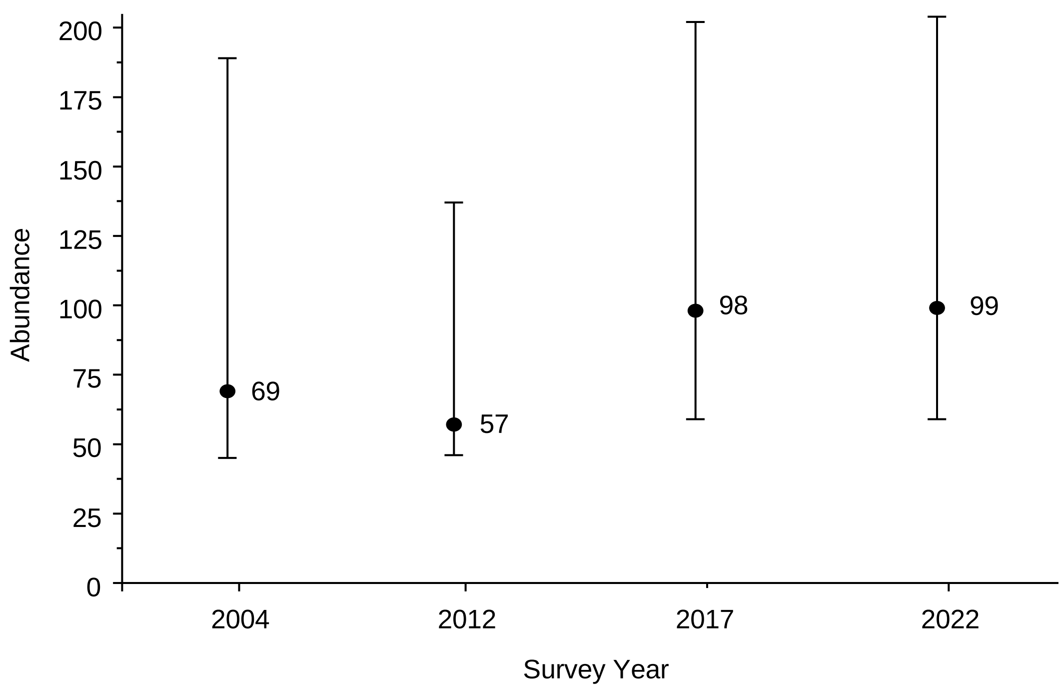

Figure 28. White Sturgeon abundance (>60 cm FL) estimates from assessments Bliss Dam to Lower Salmon Falls Dam conducted in 2004 (Lepla et al. 2004), 2012 (Bentz 2013), 2017 (Bentz and Hughes 2019) and 2022 (Bentz and Hughes, in press). Error bars represent 95% confidence intervals. (courtesy of Idaho Power Company)

Wild origin White Sturgeon make up a small proportion of the fish sampled within this reach. During the 2017 assessment, 2% (n = 1) of the fish captured had physical characteristics of wild sturgeon, 31% (n = 14) were unknown origin, and the remaining 67% (n = 30) were hatchery White Sturgeon released within the reach or that had been entrained from upstream reaches (Bentz and Hughes 2019). Of those entrained, the majority (62%) were marked in the Shoshone Falls Reach two reaches upstream. Currently, 75% of the hatchery White Sturgeon captured in the Lower Salmon Falls Reach originated upstream in the Shoshone Falls Reach. The sturgeon population in the reach appears to be partially supported by entrainment of hatchery fish or natural recruitment from upstream reaches.

Size Structure and Growth

White Sturgeon in the Bliss Dam to Lower Salmon Falls Dam reach occupy juvenile, subadult, and adult size classes. In previous assessments, sturgeon size structure was shifting to older and larger individuals; however, by the most recent assessment in 2022, stocked sturgeon had grown sufficiently to be become vulnerable to the sampling gear (Figure 29). Future population assessment should document greater representation of recent hatchery releases. Hatchery sturgeon have consistently represented most fish sampled in the reach.

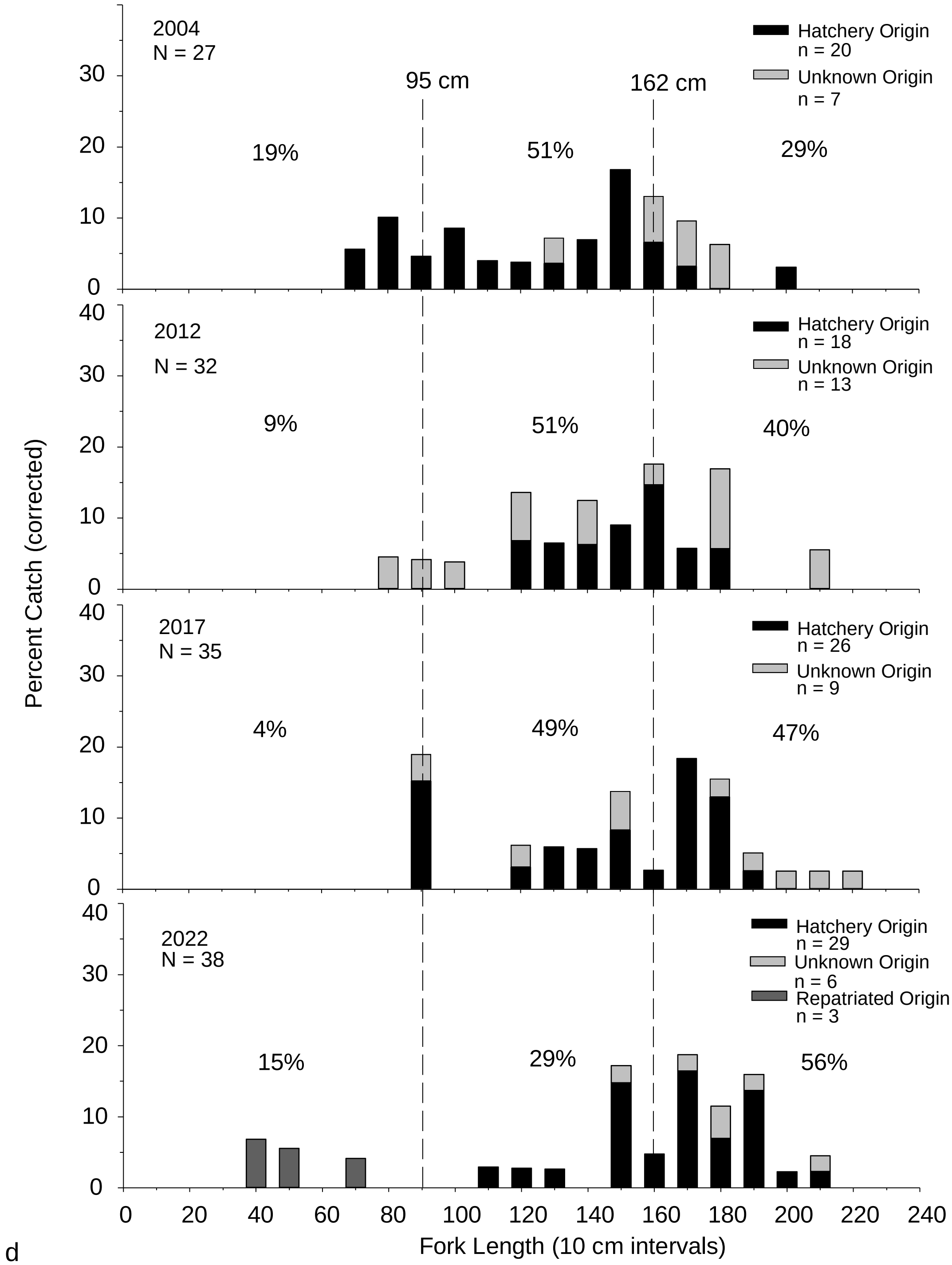

Figure 29. Length-frequency histograms of White Sturgeon captured with setlines in the Snake River between Bliss Dam to Lower Salmon Falls Dam, 2004-2022. (courtesy of Idaho Power Company)

Growth rates within this reach are comparable to other reaches with predominantly riverine habitat use. Sturgeon growth in the reach was estimated at 5.3 cm/year (Range 0 – 12.8 cm/year) based on fish captured in the river environment (Bentz and Hughes – in press). White Sturgeon are rarely sampled in Bliss Reservoir and setline surveys conducted by IPC document highest CPUE in close vicinity to Lower Salmon Falls Dam.

Survival

The Bliss Dam to Lower Salmon Falls Dam each has an overall mean annual White Sturgeon survival estimate of 0.93 (95% CI 0.86-0.97) (IPC, unpublished data). Annual survival across all life stages is comparable to other mid-Snake River reaches. Juvenile and subadult annual survival are 0.86 (95% CI 0.71-0.94) and 0.90 (95% CI 0.81-0.95) respectively. Adult sturgeon survival is estimated at 0.97 (95% CI 0.82-0.1.00). Estimated adult sturgeon survival in the Bliss to Lower Salmon Falls Reach is comparable to other mid-Snake River reaches above C.J. Strike Dam.

FISHERY MONITORING

Minimal creel data is available to characterize angling effort in the Bliss to Lower Salmon Falls reach. The prevalence of ingested metal within White Sturgeon in the reach varies by fish size and location and may be a surrogate for the intensity of angling by location. During the 2022 population assessment, the mean population rate of ingested metal across all habitats and sizes was 49% (Bentz and Hughes – in press). Metal ingestion varied by life stage with juvenile, sub-adult and adult frequency of 33, 50, and 52 percent respectively. Metal ingestion rates within this reach are the highest of any monitored reach (Appendix B).

MANAGEMENT APPROACH

Stocking

Hatchery stocking was discontinued within the reach between 1999 and 2017, due to concerns of hatchery released White Sturgeon entraining downstream and into the Core Wild reach downstream. Hatchery stocking was reinitiated beginning in 2018 and continues currently using repatriated White Sturgeon collected from the reach below (see Bliss Dam to C.J. Strike Dam section; Table 5). Fish stocked since 2018 have just begun to recruit to sampling gear. Additional hatchery sturgeon will start recruiting in the next two population assessments. Marking all released fish moving forward will allow continued monitoring of natural production and allows for the development of growth metrics between recapture events. It will also provide better knowledge of entrainment rates to the Core Conservation reach below.

IDFG will continue to manage this population under the Stocked designation using conservation aquaculture techniques, using natural-origin eggs and larvae whenever possible. Currently, target stocking rates to meet the abundance objective is 50 juveniles per year, stocked in spring (Figure 30). Stocking rates should be evaluated as needed to account for changes in growth and survival to meet population objectives.

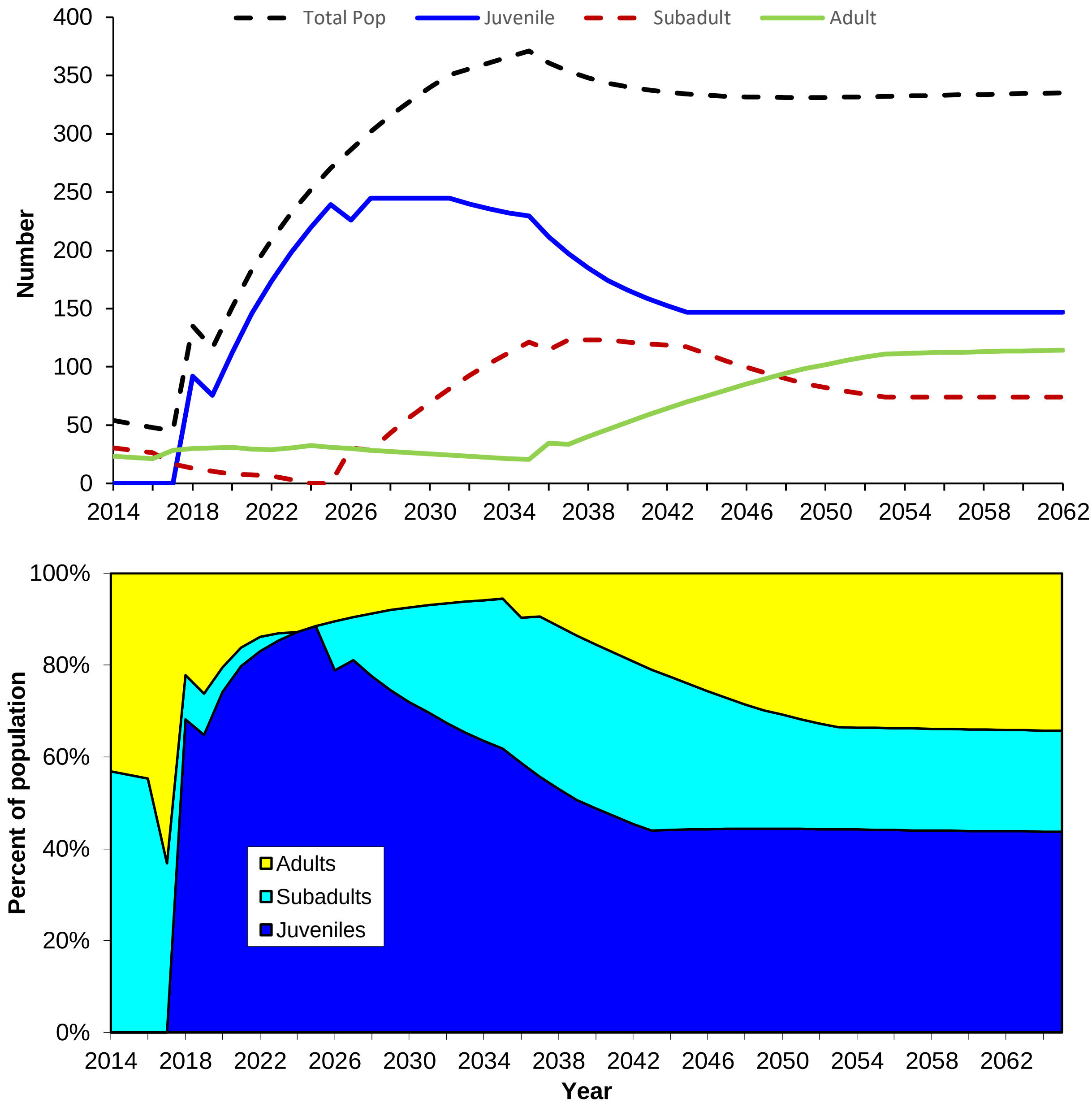

Figure 30. Model projections of White Sturgeon population from Bliss Dam to Lower Salmon Falls Dam with annual stocking of 50 juveniles. (courtesy of Idaho Power Company)

Table 5. Hatchery-reared White Sturgeon stocked in the Snake River between Bliss Dam to Lower Salmon Falls Dam. The data is from the IDFG fish stocking database.

Year Stocked	Number of fish
1989	2,171
1991	201
1994	150
1999	100
2018	92
2020	52
2021	50
Total	2,816

FUTURE WORK

- Support IPC White Sturgeon population assessments at 5-year intervals as indicated within the IPC White Sturgeon Conservation Plan.
- Stock 50 juvenile White Sturgeon annually using natural-origin eggs or larvae reared from the conservation aquaculture program. Modify stocking rates as necessary to reach population objectives.
- Evaluate entrainment rates into the reach to inform stocking objectives to maintain population abundance.
- Monitor unintentional releases of sturgeon from commercial aquaculture facilities and cull any fish of commercial facility origin, based on PIT-tag or scute marking.
- Collect creel data to estimate angler effort and catch.

LOWER SALMON FALLS DAM TO UPPER SALMON FALLS DAM

REACH METRICS

Management Designation: Stocked
Adult Population Abundance Objective: 260 fish > 162 cm FL
Adult Population Estimate, Year: 27 fish >162 cm FL, 2019
Stocking Objective: 115 Juveniles per Year

REACH DESCRIPTION

This reach is the shortest reach with approximately 1 km of free-flowing river and 10 km of reservoir habitat for White Sturgeon rearing (Figure 31). Surveys conducted from 1979 to 1981 sampled no White Sturgeon and Lukens (1981) concluded no spawning habitat was available within the reach. Water quality is suitable for sturgeon rearing most of the year but tends to decline as water flows decrease and summer air temperatures increase. Unlike the reach just upstream (Shoshone Falls to Upper Salmon Falls), spring water sources that help maintain cool summer reservoir temperatures are limited, leading to reduced habitat quality.

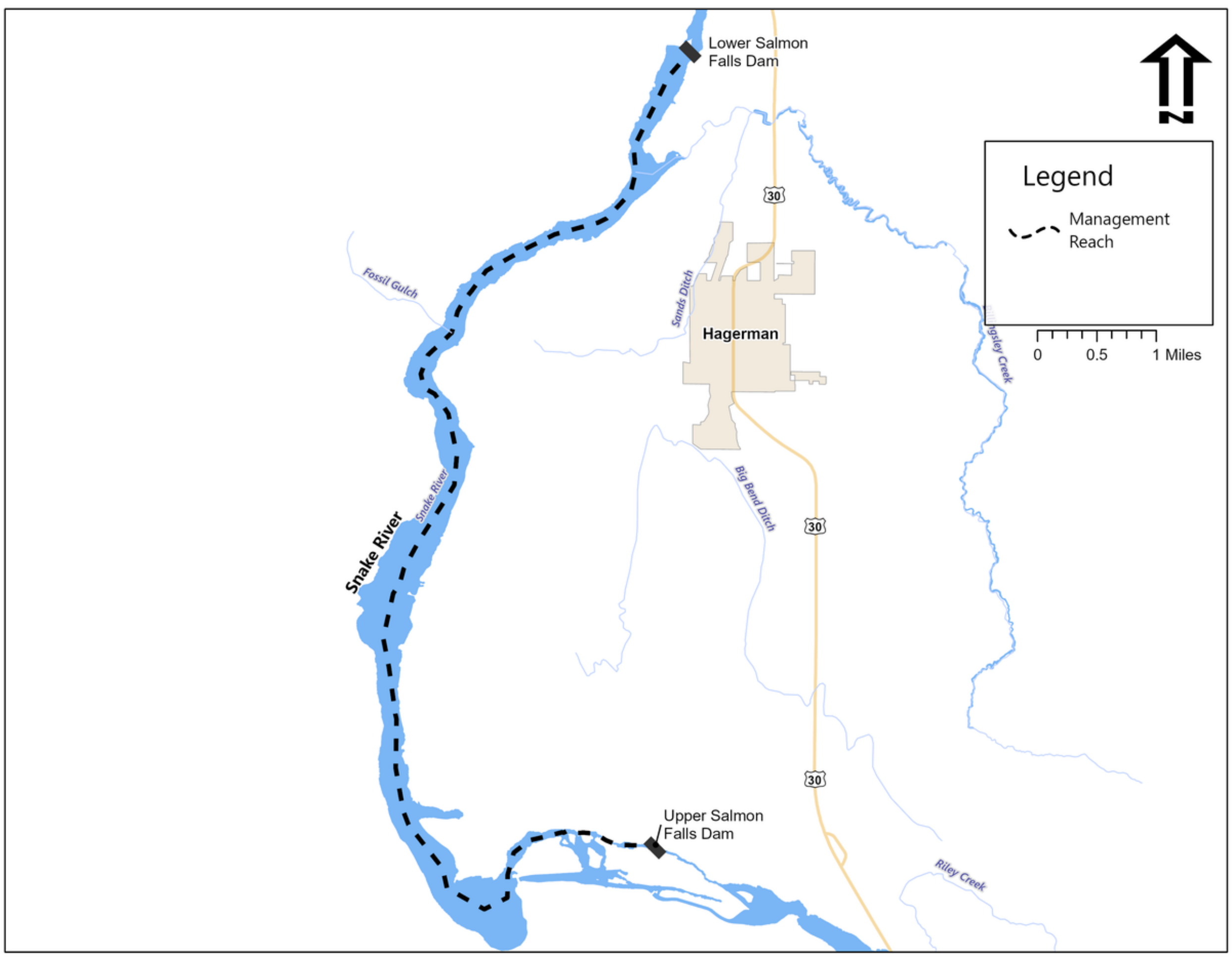

Figure 31. The Lower Salmon Falls Dam (downstream) to Upper Salmon Falls Dam (upstream) reach of the Snake River, Idaho.

POPULATION ASSESSMENTS

Similar to other mid-Snake reaches, the current population monitoring metrics include abundance, density, biomass, size structure, condition factor, growth rates, and apparent survival. Idaho Power Company currently conducts population assessments approximately every five years in association with their FERC-license requirements. The 2019 population estimate was 27 sturgeon (>60 cm FL) and indicated a significant abundance decrease since 2014 (N = 88) but was similar to the 2004 assessment (Figure 32). White Sturgeon densities have ranged from 0.1 to 0.3 sturgeon/ha (Bentz and Hughes 2020c). The adult abundance objective for the reach is 260 fish (>160 cm FL), which is 14-fold higher than the current estimate of 27 adult White Sturgeon. Mean relative weight of sampled sturgeon was 93 and stable when compared to past assessments (Bentz and Hughes 2020c).

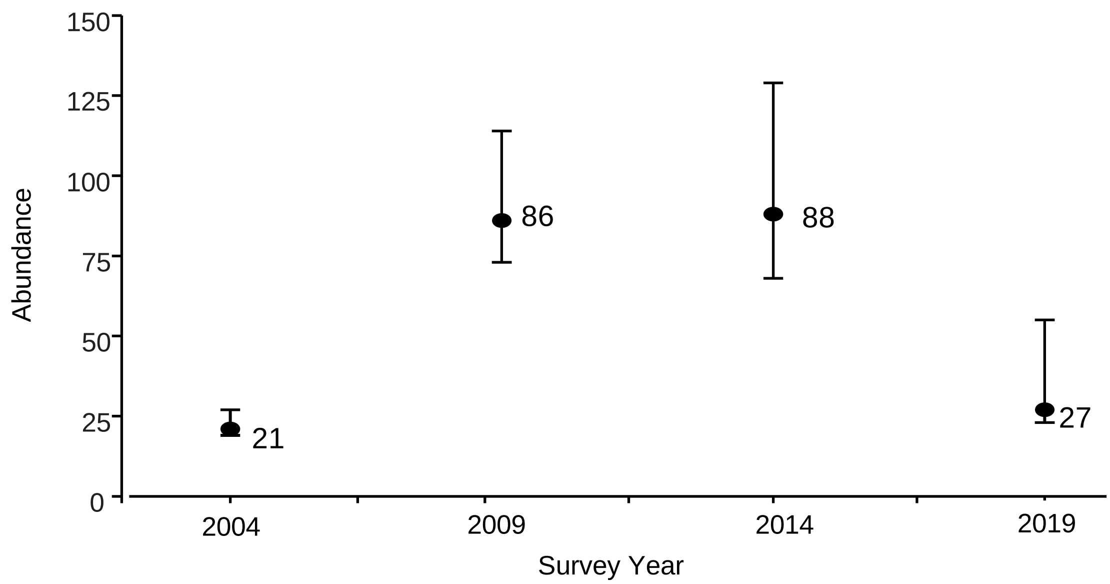

Figure 32. White Sturgeon abundance (>60 cm FL) estimates from assessments conducted in 2004 (Lepla et. al 2004), 2009 (Bentz 2010), 2014 (Bentz 2015b) and 2019 (Bentz and Hughes 2020c) from Lower Salmon Falls Dam to Upper Salmon Falls Dam. Error bars represent 95% confidence intervals. (courtesy of Idaho Power Company).

Size Structure and Growth

Though sample size and abundance continue to be low, all vulnerable size classes (juvenile, sub adult, and adult) were sampled in 2019 (Figure 33). The diversity of size classes is likely a result of downstream entrainment, hatchery stocking, and unintentional releases or escape of hatchery White Sturgeon from commercial facilities.

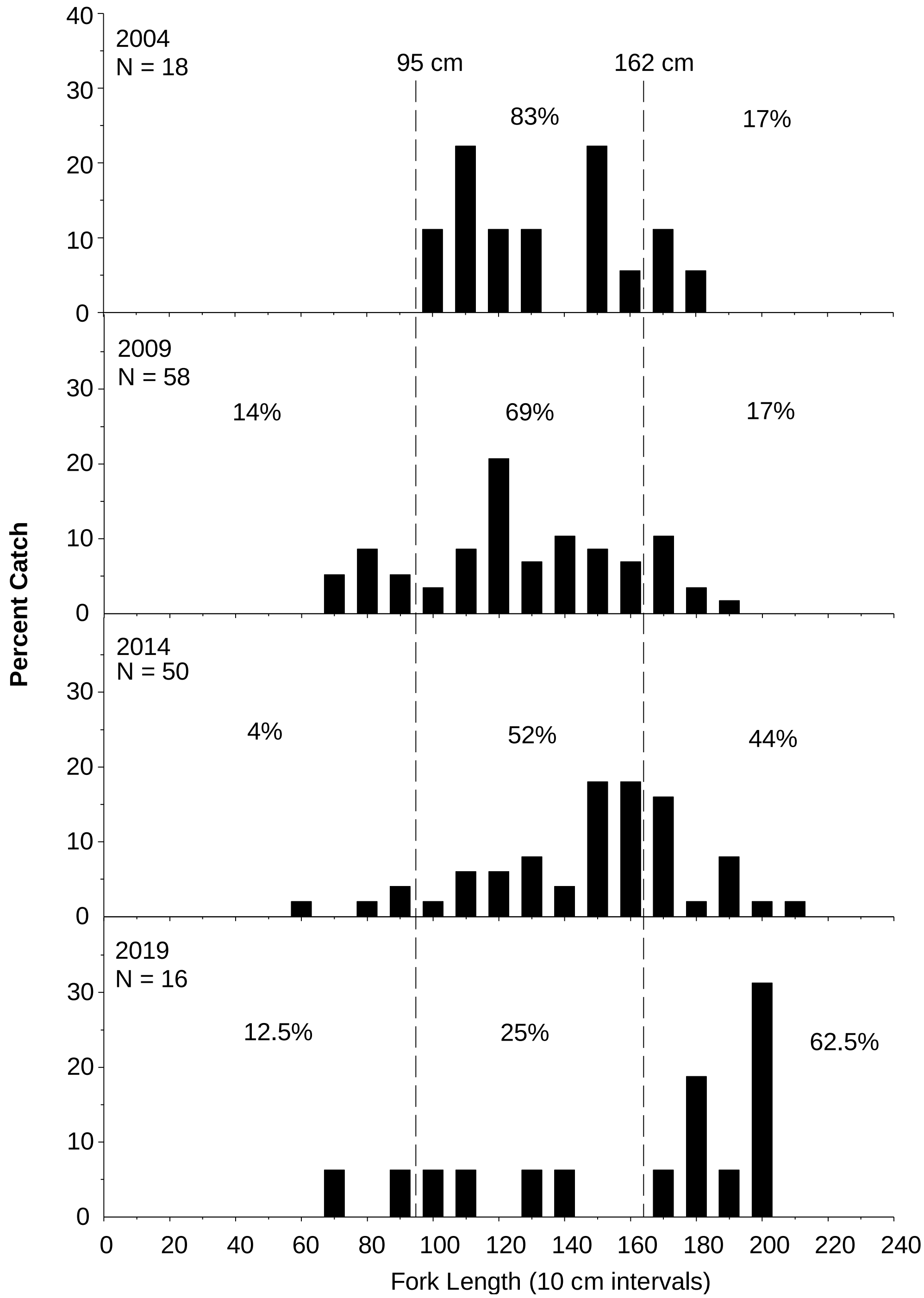

Figure 33. Length-frequency histograms of White Sturgeon captured with setlines in the Snake River between Lower Salmon Falls Dam and Upper Salmon Falls Dam during 2004 (a), 2009 (b), 2014 (c), and 2019 (d). (courtesy of Idaho Power Company)

IPC was recently able to describe White Sturgeon growth in the Lower Salmon Falls Dam to Upper Salmon Falls Dam reach. Annual growth averaged 6.8 cm/year (n = 31) (Bentz and Hughes 2020c). This growth rate is faster than other reaches in the middle Snake River. It is unclear if the faster growth rates are due to the low density within the reach or environmental factors.

Survival

The Lower Salmon Falls to Upper Salmon Falls Reach has an overall mean annual White Sturgeon survival estimate of 0.94 (95% CI, 0.74-0.99; IPC, unpublished data). Annual mean survival across all life stages is comparable to other mid-Snake River reaches above C.J. Strike Dam. Juvenile and subadult annual survival are 0.96 (95% CI 0.48-0.1.00) and 0.94 (95% CI 0.80-0.98) respectively. Adult sturgeon survival was not estimated in the reach because of inadequate sample sizes.

FISHERY MONITORING

Minimal creel data is available to characterize angling effort in the Lower Salmon Falls Dam to Upper Salmon Falls Dam reach. The prevalence of ingested metal within White Sturgeon in the reach may be a surrogate for the intensity of angling by location. During the 2019 population assessment, the mean population rate of ingested metal across all habitats and sizes was 12.5% (IPC 2020; also see Appendix B). Metal ingestion by life stage was not calculated due to low sample size.

MANAGEMENT APPROACH

Stocking

Early survey work concluded that inadequate spawning habitat existed to support natural recruitment between Lower Salmon Falls Dam and Upper Salmon Falls dam (Lukens 1981). The current population is comprised of predominantly hatchery-reared White Sturgeon. Sturgeon captured using setline gear, during the 2019 assessment, were 83% hatchery origin and 17% unknown origin (Bentz and Hughes 2020c). Only one unmarked White Sturgeon was captured that appeared to have wild physical characteristics. Unmarked White Sturgeon (47-86%) are routinely encountered during population assessments in the Upper Salmon Falls reach and many of them have physical characteristics consistent with hatchery origin fish, which may suggest some of these individuals may originate from nearby commercial aquaculture facilities (Bentz and Hughes 2020c). IDFG supports culling of sturgeon captured in the reach which are documented to originate from commercial facilities.

Hatchery stocking has occurred within the reach since 2000 (Table 6.). Most of the hatchery White Sturgeon released during the past two years are too small to be encountered with standard sampling gear. As they age and grow, these cohorts will be encountered more frequently during the next two population assessments. Marking and tagging all hatchery fish allows us to continue to monitor for natural production and allows for the assessment of growth between recapture events. It will also help estimate entrainment rates among the different river reaches. Though natural recruitment is currently minimal, research to assess current habitat or demographic limitations to natural recruitment should be evaluated.

Table 6. Hatchery-reared White Sturgeon stocked in the Snake River between Lower Salmon Falls Dam and Upper Salmon Falls Dam. The data is from the IDFG fish stocking database.

Year Stocked	Number of fish
2000	46
2014	6
2015	1
2020	115
2021	116
Total	284

Idaho Fish and Game will continue to manage this population with the Stocked designation strategy using conservation aquaculture techniques, using natural-origin eggs and larvae whenever possible. The current target stocking rate of 115 juveniles stocked annually in the spring is estimated to meet the abundance objective (Figure 34). Stocking rates should be evaluated in the future and adjusted as needed to account for changes in growth and survival to meet target population objective.

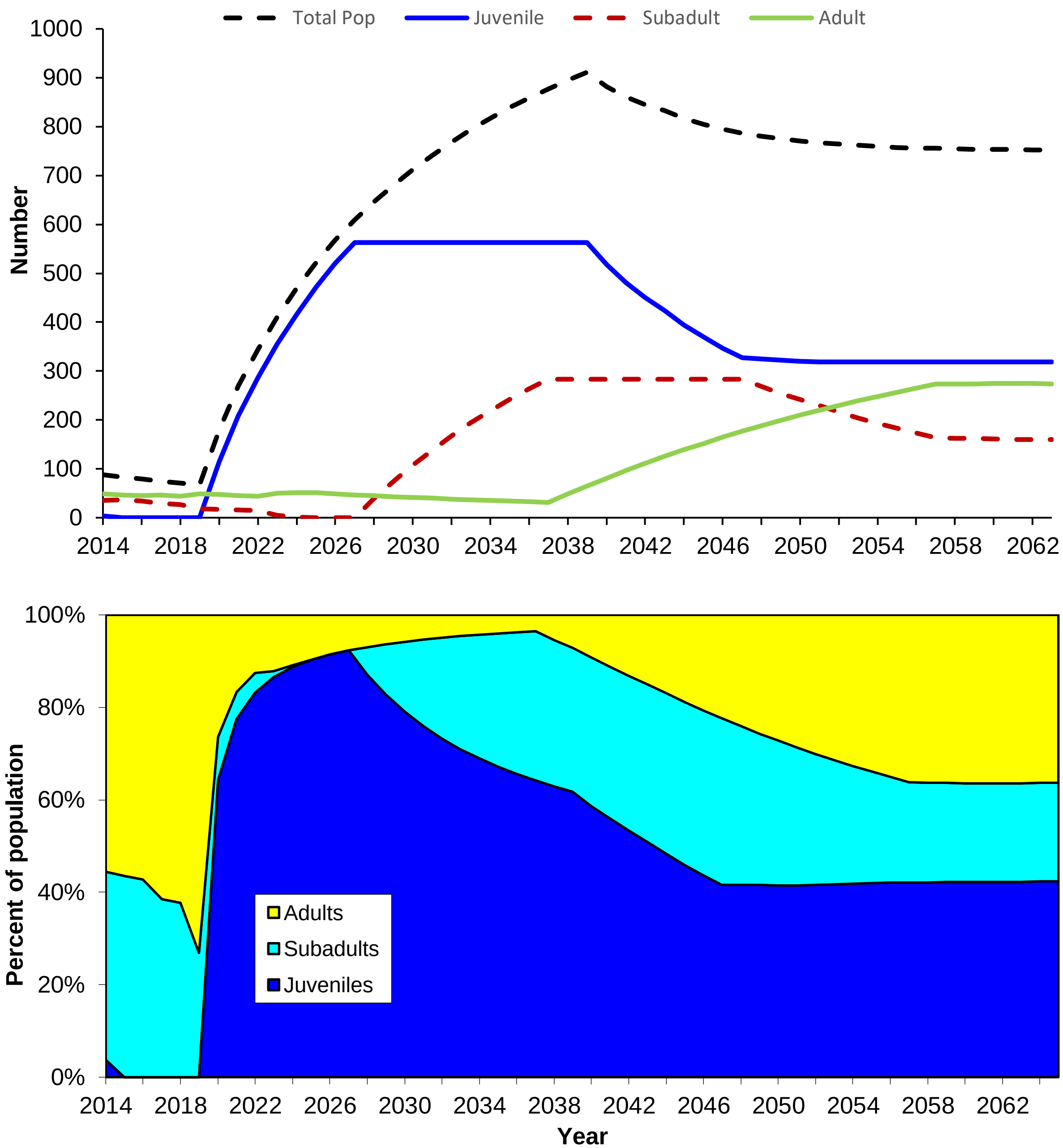

Figure 34. Model projections of White Sturgeon population from Lower Salmon Falls Dam to Upper Salmon Falls Dam with annual stocking of 115 juveniles. (courtesy of Idaho Power Company)

FUTURE WORK

- Support IPC White Sturgeon population monitoring at 5-year intervals as indicated within the IPC White Sturgeon Conservation Plan.
- Stock 115 juvenile White Sturgeon annually using natural-origin eggs or larvae through conservation aquaculture. Modify stocking rates as necessary to reach population objectives.
- Evaluate entrainment rates into the reach to inform stocking objectives and maintain or increases population abundance.
- Monitor unintentional releases of sturgeon from commercial aquaculture facilities and cull any fish of commercial facility origin, based on PIT-tag or scute marking.
- Assess limiting factors to natural recruitment in the reach and implement management strategies based on findings to promote natural recruitment.
- Collect creel data to estimate angler effort and catch.

UPPER SALMON FALLS DAM TO SHOSHONE FALLS

REACH METRICS

Management Description: Stocked
Adult Population Abundance Objective: 450 fish >162 cm FL
Adult Population Estimate: 154 fish >162 cm FL, 2022
Stocking Objective: 200 Juveniles per Year

REACH DESCRIPTION

The Upper Salmon Falls Dam to Shoshone Falls reach is 54 km in length and is comprised of 47 km of free-flowing river and 7 km of reservoir habitat (Figure 35). This reach is the uppermost native range of White Sturgeon in the Snake River. Shoshone Falls is a natural 65 m tall waterfall, which limits upstream fish migration. Flow management due to irrigation diversions and hydropower projects affects this reach substantially. The hydrograph can be bimodal during the spawning season. River flows tend to increase in the spring until irrigation withdrawals start, stabilize, and then may increase a second time, during high water years, when irrigation and storage capacity in upstream reservoirs is exceeded. Often, all water within the Snake River at Milner Dam is diverted into irrigation diversions leading to very low inputs to this reach. Downstream of Milner Dam, most of the water found within this reach of the Snake River is due to natural springs that enter the river downstream of Shoshone Falls. These springs are largely groundwater discharge from the Eastern Snake River Plain Aquifer. The bulk of this water enters the river at the Thousand Springs area near Hagerman, Idaho. Several large rapids in this reach can provide adequate spawning velocities and habitat types, but the overall short reach length limits natural recruitment within the reach. The altered hydrograph can also remove or shift the river’s flows out of synchrony with suitable spawning temperatures.

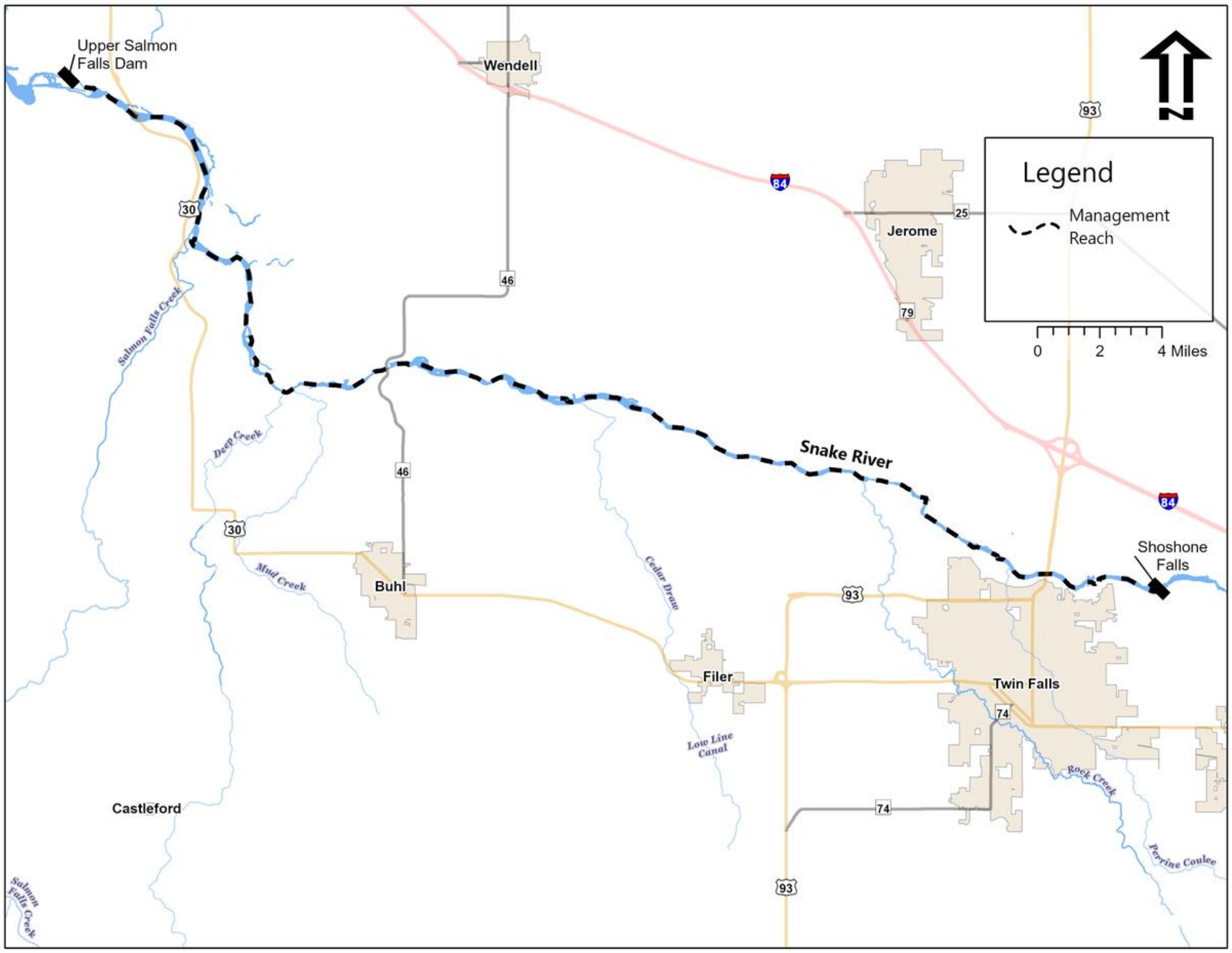

Figure 35. The Upper Salmon Falls Dam (downstream) to Shoshone Falls (upstream) reach of the Snake River, Idaho.

POPULATION ASSESSMENTS

Recent population monitoring metrics include abundance, density, biomass, size structure, condition factor, growth rates, and apparent survival. Idaho Power Company currently conducts population assessments approximately every five years in association with their FERC-license requirements.

Population Estimate

The reach is surveyed using four sampling sections (Bentz and Hughes 2020b). The 2018 population assessment indicated that this population has been relatively stable for the last 15 years (Figure 36). Setline CPUE in 2018 of 0.021 fish/h and was similar to estimates in 2001 and 2008 (Bentz and Hughes 2020b). IDFG worked with IPC to develop population targets within the reach. The current abundance estimate of 349 White Sturgeon (>60 cm FL) is less than the population objective of 450 fish.

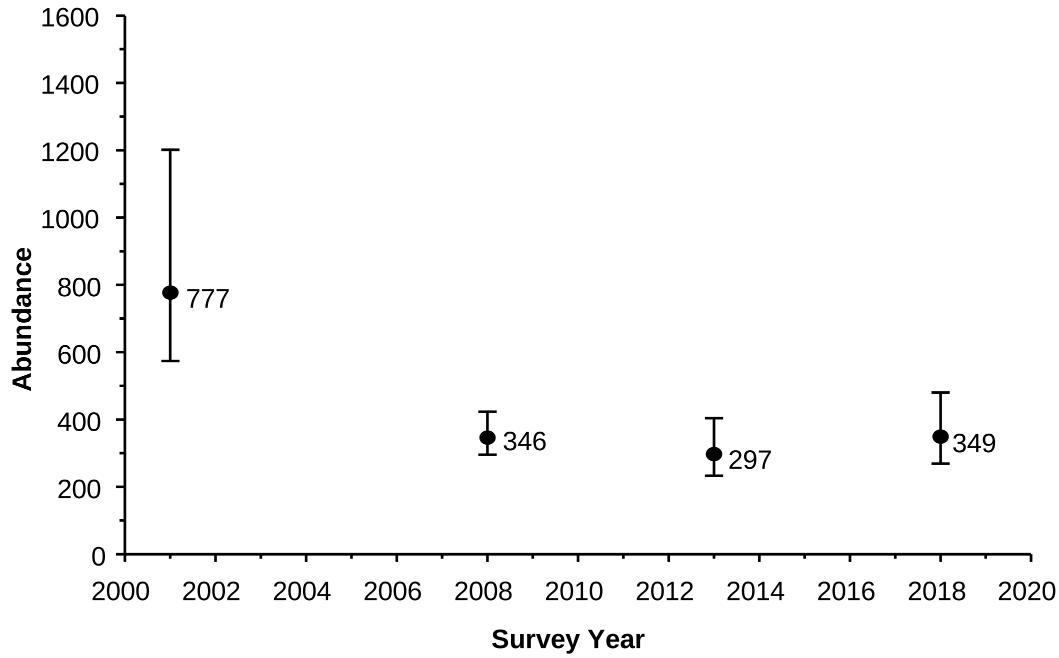

Figure 36. White Sturgeon abundance (>60 cm FL) estimates from assessments conducted in the Upper Salmon Falls Dam to Shoshone Falls reach in 2001 (Lepla et al. 2002), 2008 (Bentz and Lepla 2009), 2013 (Bentz 2014) and 2018 (Bentz and Hughes 2020b). Error bars represent 95% confidence intervals. (courtesy of Idaho Power Company)

Size Structure and Growth

The population assessment conducted in 2018 captured smaller size classes of White Sturgeon which documents recruitment of stocked sturgeon into the reach to eventually replace the aging adult size classes which continue to trend to larger size classes (Figure 37).

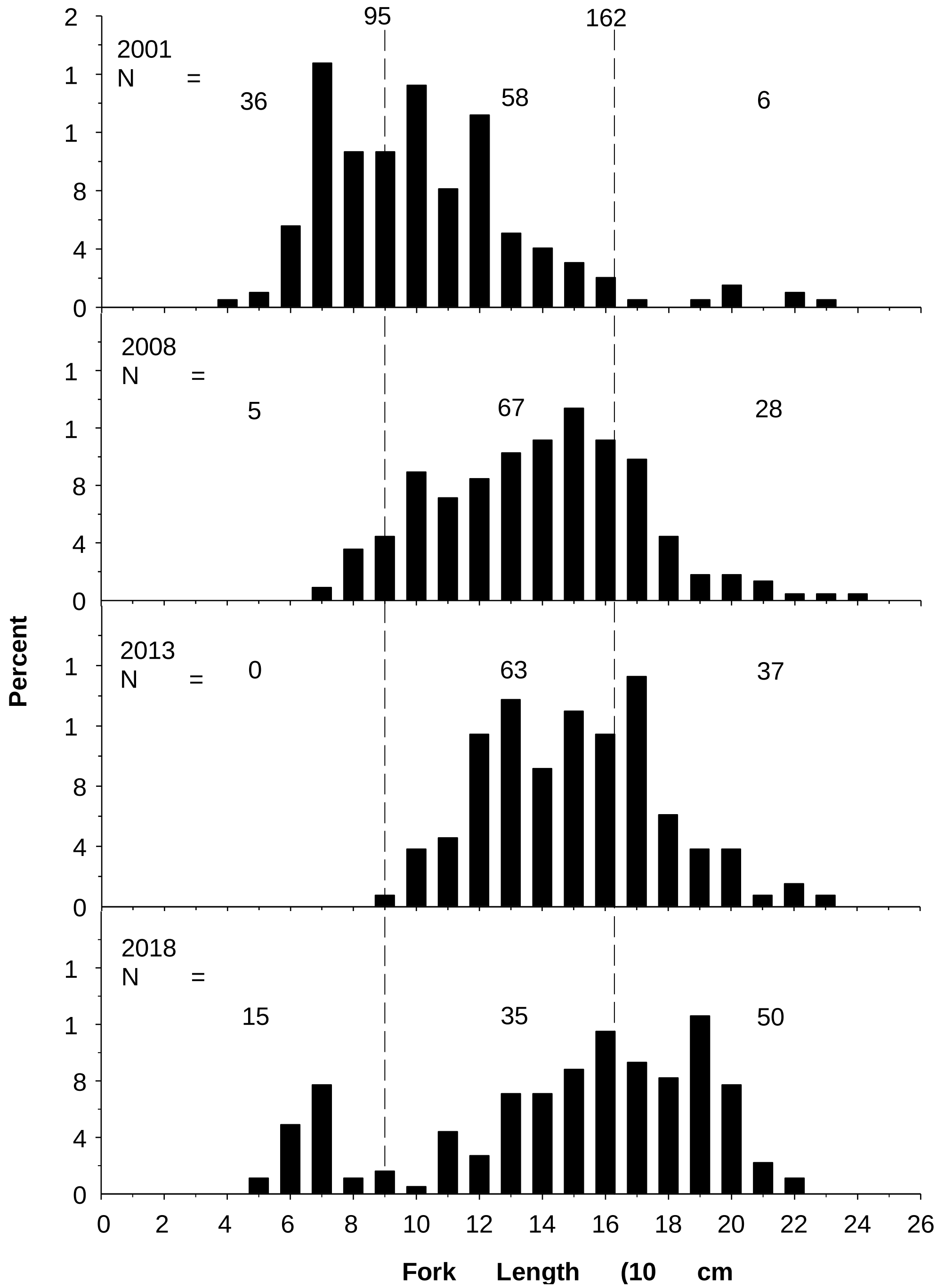

Figure 37. Length-frequency histograms of White Sturgeon captured with setlines in the Snake River between Upper Salmon Falls Dam and Shoshone Falls, (a) 2001, (b) 2008, (c) 2013, and (d) 2018. (courtesy of Idaho Power Company).

Mean relative weight of sturgeon sampled during 2018 was lower than any of the previous assessments (Table 7). Decreases in relative weights were observed across all White Sturgeon life stages (Table 7) Similar to other reaches, which contain different habitat types (reservoir vs. riverine), growth rates within the reach vary widely but overall, the population exhibits good growth rates when compared to other populations in native reaches of the Snake River (Bentz and Hughes 2020b).

Table 7. Mean relative weight (standard = 100) by population group of White Sturgeon sampled with setlines in the Snake River between Upper Salmon Falls Dam and Shoshone Falls. Sample sizes are in parentheses (courtesy of Idaho Power Company).

Survey Year	All WS (n)	p-value	Juvenile (n)	p-value	Sub-adult (n)	p-value	Adult (n)	p-value
2001	101 (193)	–	97 (69)	–	104 (114)	–	88 (11)	–
2008	96 (219)	0.0005	88 (12)	0.096	97 (145)	0.0006	93 (62)	0.228
2013	89 (127)	<0.0001	–	–	90 (78)	0.0002	88 (49)	0.016
2018	83 (180)	<0.0001	85 (28)	–	79 (63)	<0.0001	84 (89)	0.07

Survival

The Upper Salmon Falls to Shoshone Falls Reach has an overall mean annual White Sturgeon survival estimate of 0.95 (95% CI, 0.94-0.96; IPC, unpublished data). Annual survival across all life stages is comparable to other mid-Snake River reaches above C.J. Strike Dam. Juvenile and subadult annual survival are 0.98 (95% CI, 0.92-0.99) and 0.95 (95% CI, 0.93-0.96), respectively. Adult sturgeon survival was estimated as 0.95 (95% CI 0.90-0.0.97). Estimated adult sturgeon survival in the Bliss to Lower Salmon Falls Reach is comparable to other mid-Snake River reaches upstream of C.J. Strike Dam.

FISHERY MONITORING

Minimal creel data is available to characterize angling effort in the Upper Salmon Falls Dam to Shoshone Falls reach. The prevalence of ingested metal within White Sturgeon in the reach may be a surrogate for the intensity of angling by location. During the 2018 population assessment, the mean population rate of ingested metal across all habitats and sizes was 13% (IPC 2020; also see Appendix B). Metal ingestion varied by life stage with juvenile, sub-adult, and adult frequency of 0%, 14%, and 16%, respectively.

MANAGEMENT APPROACH

Stocking

The current population is comprised of predominantly hatchery White Sturgeon and limited evidence of wild recruitment in the reach (Bentz and Hughes 2020b). Sturgeon captured using setline gear, during the 2018 assessment, were 92.4% hatchery, 6.0% unknown, and 1.6% natural origin (Bentz and Hughes 2020b). Stocking has been occurring in the reach since 1989 though hatchery releases did not occur from 1999-2010 (Table 8.). A total of 2,025 hatchery White Sturgeon have been released within the reach at six release sites (Table 8). Marking and tagging all released sturgeon will allow us to continue to monitor for natural production and allows for the development of growth metrics between recapture events. These marks and tags also help identify entrainment rates between the different river reaches. Though natural recruitment is currently minimal, research to assess current habitat or demographic limitations to natural recruitment should be evaluated.

Table 8. Hatchery-reared White Sturgeon stocked in the Snake River between Upper Salmon Falls Dam and Shoshone Falls, 1989-2017 (courtesy of Idaho Power Company).

Year Stocked	Year Class	Number of fish
1989	1988	3
1990	1988	133
1991	1990	483
1994	1993	280
1997	1995	123
1999	1997	159
2010	n/a	49
2014	2012	200
2016	2015	188
2017	2016	150
2020	2019	65
2021	2020	192
Total		2,025

The continued use of stocking is currently necessary to increase recruitment of juvenile sturgeon and achieve abundance objectives in the reach. IDFG will continue to manage this population under the Stocked designation using conservation aquaculture techniques, using natural-origin eggs or larvae whenever possible. The target stocking rate of 200 juveniles per year, stocked in spring is expected to meet population abundance objectives (Figure 38). The stocking rate should be evaluated in the future to account for changes in growth and survival to meet target population objectives.

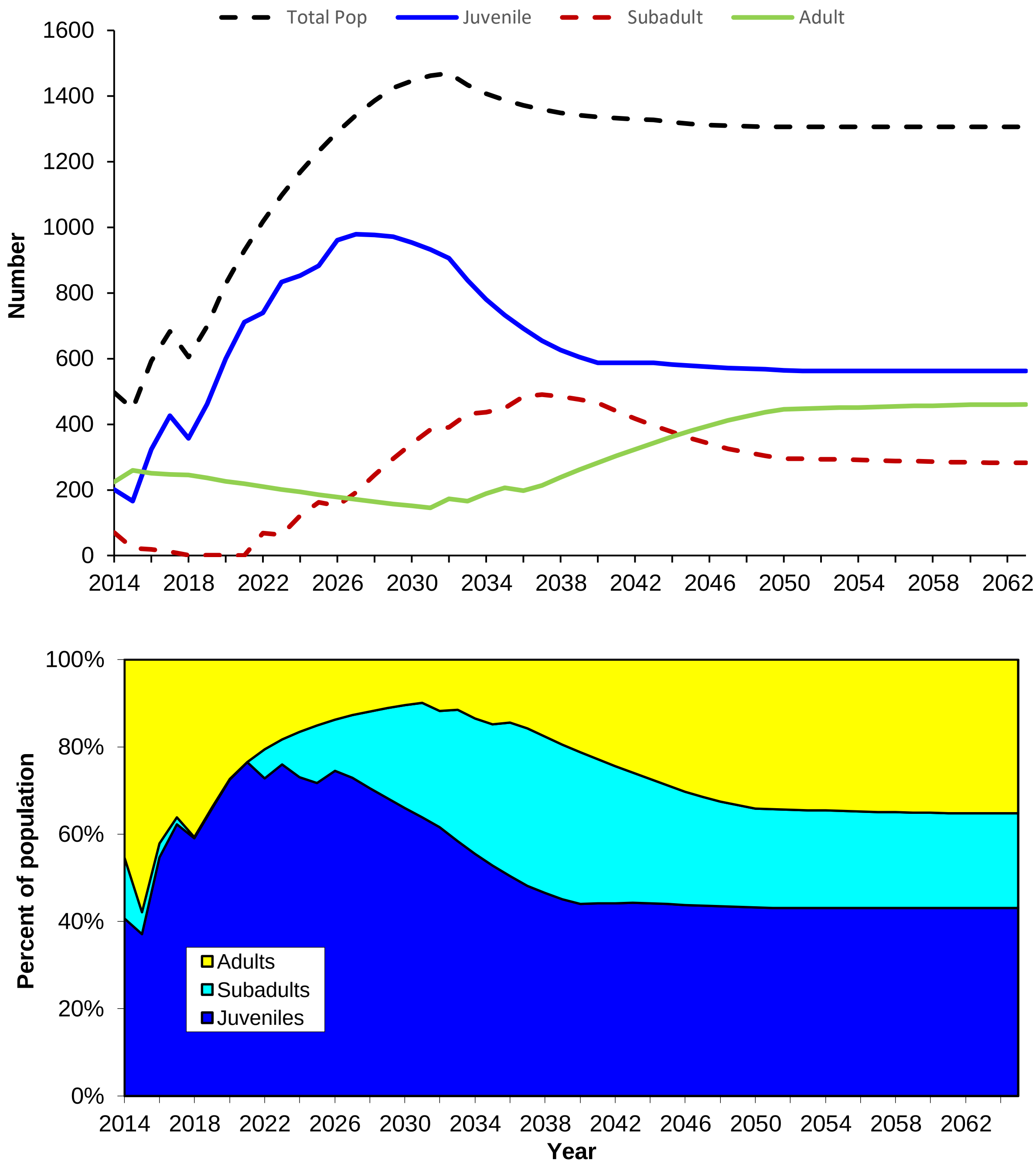

Figure 38. Model projections of White Sturgeon population from Upper Salmon Falls Dam to Shoshone Falls with annual stocking of 200 juveniles. (courtesy of Idaho Power Company)

FUTURE WORK

- Support IPC White Sturgeon population monitoring at 5-year intervals as indicated within the IPC White Sturgeon Conservation Plan
- Stock 200 juvenile White Sturgeon annually using natural-origin eggs/larvae through conservation aquaculture
- Assess limiting factors to natural recruitment in the reach and implement management strategies based on findings to promote natural recruitment.
- Evaluate entrainment rates into the reach to inform stocking objectives and maintain or increases population abundance.
- Monitor unintentional releases of sturgeon from commercial aquaculture facilities and cull any fish of commercial facility origin, based on PIT-tag or scute marking.
- Collect creel data to estimate angler effort and catch.
- Assess effects of water quality impairment which may affect sturgeon population abundance.

SNAKE RIVER UPSTREAM OF SHOSHONE FALLS

REACH METRICS

Management Designation: Non-native range
Population Estimate, Year: Not available
Stocking Objective: 200 juveniles per year, contingent on meeting release objectives in downstream reaches

REACH DESCRIPTION

The Snake River upstream of Shoshone Falls, is upstream of the historical range for White Sturgeon; however, stocking has occurred in these reaches since the mid-1990s. Given the unique designation and similarities of these reaches this portion of the management plan will be presented in combination White Sturgeon, specifically Population Status/Previous Work, Data Gaps, and Future Work. However, reach descriptions and previous hatchery releases are presented individually since regulation structure and management may occur in the future on an individual reach basis above Shoshone Falls.

The intent of White Sturgeon introductions above Shoshone Falls was to diversify angling opportunity. Specifically, management intent has focused on providing trophy, non-salmonid angling opportunity compatible with the existing wild- and hatchery-supported salmonid fisheries. Although a formal, quantitative assessment of available White Sturgeon habitat in the upper Snake River has not been conducted, it is thought that adult habitat is patchily distributed and low in quantity relative to reach length. While White Sturgeon are frequently encountered throughout the reaches, with the highest densities generally occurring immediately below dams and diversions. In fact, the vast majority of White Sturgeon angling activity appears to occur in the American Falls and Gem Dam tailraces. Idaho Fish and Game observations of or contacts with White Sturgeon anglers in other locations throughout these reaches are rare.

Minidoka Dam to American Falls

The morphology and habitat of the Snake River changes drastically below American Falls Dam. The Minidoka Dam to American Falls Dam reach is approximately 64 km long with 29 km of free-flowing river and 35 km of lentic habitat within Lake Walcott. Between American Falls Dam and Lake Walcott, the river flows through a pronounced desert canyon with macrohabitat features punctuated by large basalt formations. The natural flow restriction point at the location of present-day American Falls Dam (near the town of American Falls, ID) affected a natural transition from braided to a confined, partially meandering channel. This transition subsequently affects substrate composition, riparian vegetation composition, as well as floodplain size and connectivity. Floodplain habitat is uncommon within this reach with the exception of several small terrestrial islands near the downstream terminus.

This reach of the Snake River is highly regulated by American Falls Dam operations. American Falls Dam is a Bureau of Reclamation facility that was built in 1927. It is a 28-m tall composite concrete and earth structure that has a storage capacity of approximately 1,600,000 acre-ft. The principal function of the American Falls dam-reservoir system is to store and deliver irrigation water to the Magic Valley region. The dam was modified in 1979 to address concrete degradation and, at that time, was also retrofitted with a powerhouse to accommodate power production. Idaho Power Company operates the power production facility in cooperation with the Bureau of Reclamation. Flows in this reach are highly variable and inconsistent with natural regimes due to reservoir storage and water delivery operations. Mean winter discharge in the tailrace (measure at the U.S. Geologic Survey gauge near Neeley) are generally 300–400 cfs due to the "Two Rivers policy; zero flow at Milner Dam decree." Under this flow management regime, winter flow in the American Falls Dam tailrace is restricted "to secure as nearly as possible a total use of the upstream derived water for irrigation and to secure the greatest possible use for power below Milner Dam." Conversely, mean summer discharge is routinely very high and often exceeds 15,000 cfs during peak irrigation demand. High summer and early fall discharge is generally associated with impaired water quality. Due to the existing flow management regime and the reach substrate composition, little to no White Sturgeon natural recruitment is expected. Even under scenarios of successful spawning, early rearing and overwinter habitat for juvenile White Sturgeon is nearly nonexistent in this reach.

Water quality conditions in the tailrace are highly variable based on water management operations and can be problematic for supporting coolwater fish species like White Sturgeon. Based on angler feedback and biologist observations of the fishery, the majority of White Sturgeon in this reach reside in the reservoir tailrace, within 400 m of the dam. During most years, dissolved oxygen content in the reservoir hypolimnion degrades throughout the summer, and low to zero dissolved oxygen content water is often delivered downstream. This has resulted in substantial fish kills in the past that have affected White Sturgeon populations, particularly an August 2018 event. Although low dissolved oxygen (i.e., < 6 mg/l) conditions are often present through the late summer through early fall, mitigation measures (epilimnetic spill; atmospheric turbine penstock blowers) are in place to maintain tailrace dissolved oxygen ≥ 3.5 mg/l. Following the American Falls Dam rebuild, and powerhouse retrofit, a dissolved oxygen content minimum was established in state rule for this reach of the Snake River. While maintenance of dissolved oxygen above 3.5 mg/l generally prevents direct mortality of White Sturgeon, it is thought to severely affect angling catch rates. Fishery observations generally show a pattern of decreased White Sturgeon catch corresponding to low tailrace dissolved oxygen, presumably due to reduced metabolic demand and feeding activity. As such, one of the main limitations to supporting consistency in the fishery has been tailrace water quality.

American Falls Dam to Gem Lake Dam

The Snake River between Gem Lake Dam and American Falls Dam is approximately 117 km in length and includes a diverse suite of habitats. The majority (89 km) of the reach is free-flowing river and the remaining portion of the reach includes American Falls Reservoir (Figure 39). The river is highly altered by water and land use development; thus, regulated flows limit floodplain connectivity and moderate discharge. In addition, water use has resulted in a network of diversions and canals to deliver irrigation water to agricultural lands.

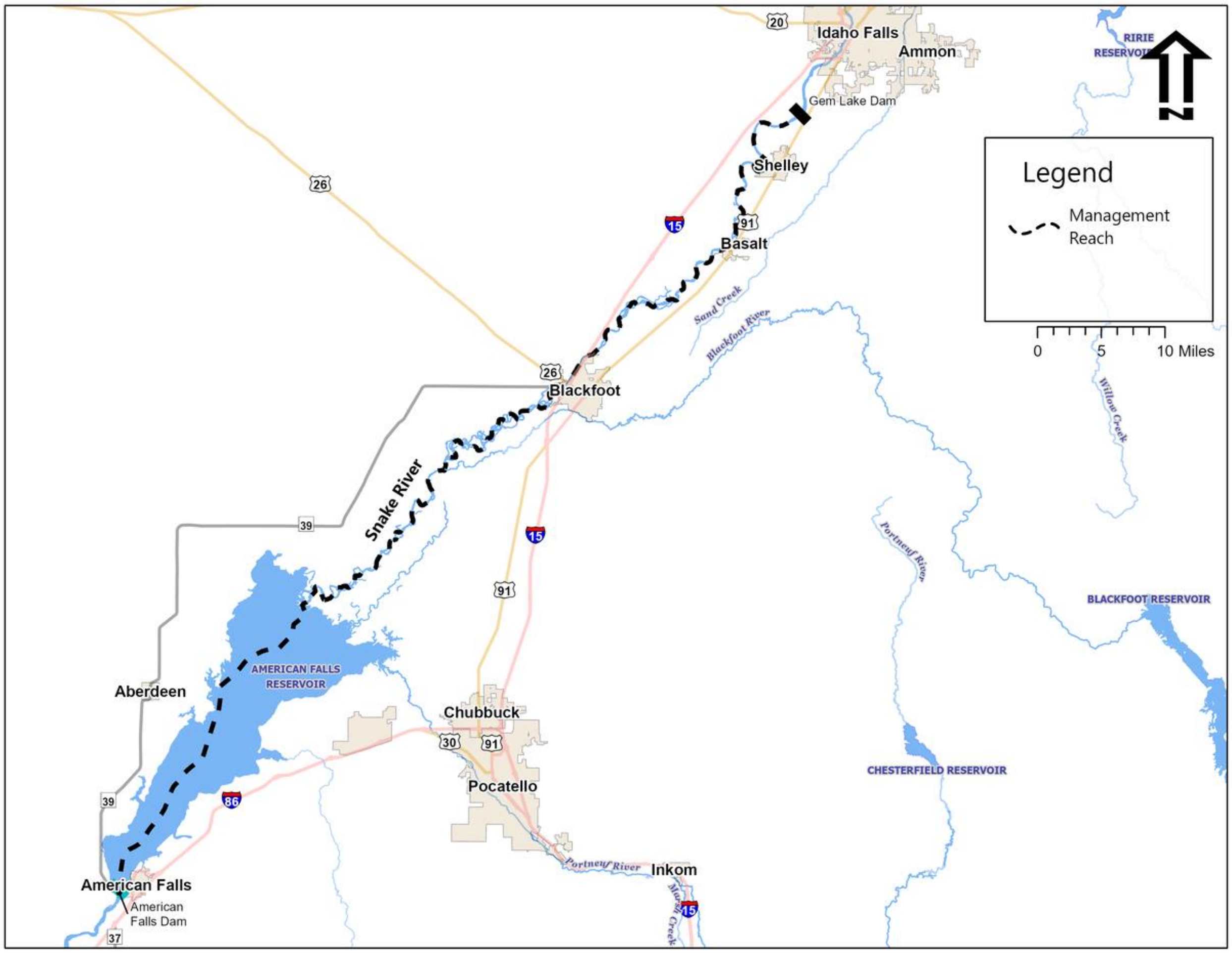

Figure 39. The American Falls Dam (downstream) to Gem Lake Dam (upstream) reach of the Snake River, Idaho.

From the Gem Lake Dam tailrace to near the Bingham-Bonneville county line, the Snake River follows a southwest course through a leveed channel adjacent to developed agricultural lands for approximately 18.5 km to the town of Firth, ID. Near Firth, the channel becomes braided and flows through a less developed floodplain characterized by an intact cottonwood-willow gallery. Here, the Snake River more often interacts with its terrestrial floodplain, even with flow modification, and is somewhat characteristic of pre-development conditions. Some adjacent lands are not susceptible to flooding and are managed as irrigated livestock pasture or for row crop production. Undeveloped terrestrial floodplain habitat in this reach is generally managed for livestock grazing or unused. The Snake River flows another 71 km from Firth to the American Falls Reservoir interface (at full pool). The river is relatively dynamic through this section, apart from a 7.4 km straightened reach through the town of Blackfoot and displays some channel migration and change when high runoff permits. During the warmest periods of the year (i.e., July–August), the Snake River cools substantially below Ferry Butte due to a series of cold spring inputs along the McTucker and Fort Hall bottoms.

Gem Lake Dam to Lower Power Plant Dam

The Gem Lake Dam to Lower Power Plant Dam reach is located in the Upper Snake Region and is bounded by the Idaho Falls Power Company's Gem Lake Dam downstream and Lower Power Plant Dam upstream (Figure 40). This reach is approximately 7.0 river km in length. The reach is comprised of the run-of-the-river reservoir with free-flowing river in the upper half and shallow (<5 m) slack water in the lower half. Sturgeon are predominately found in the upper reach in proximity to Lower Power Plant Dam.

Lower Power Plant Dam to Idaho Falls Dam

The Lower Power Plant Dam to Idaho Falls Dam reach is located in the Upper Snake Region and is bounded by Idaho Falls' namesake river feature near the Broadway Bridge at the upstream boundary and the Idaho Falls Power Company's Lower Power Plant downstream. This reach is approximately 3.2 river km in length comprised predominately of free-flowing river (Figure 40). The reach has a variety of habitat types including basalt rimrock lined pools, deep runs, and short slack water section immediately above Lower Power Plant Dam.

Idaho Falls Dam to Upper Power Plant Dam

Idaho Falls Dam to Upper Power Plant Dam reach is approximately 8 km long comprised predominately of free-flowing river and is currently the uppermost distribution of White Sturgeon in the Snake River drainage (Figure 40). The reach is bounded by the Idaho Falls Power Company's Upper Power Plant upstream and Idaho Falls' namesake river feature near the Broadway Bridge at the downstream boundary. The reach includes a natural pool located at the State Highway 20 bridge known as John's Hole. The river contains depths of approximately 30 m at this site and is the best sturgeon habitat in the reach.

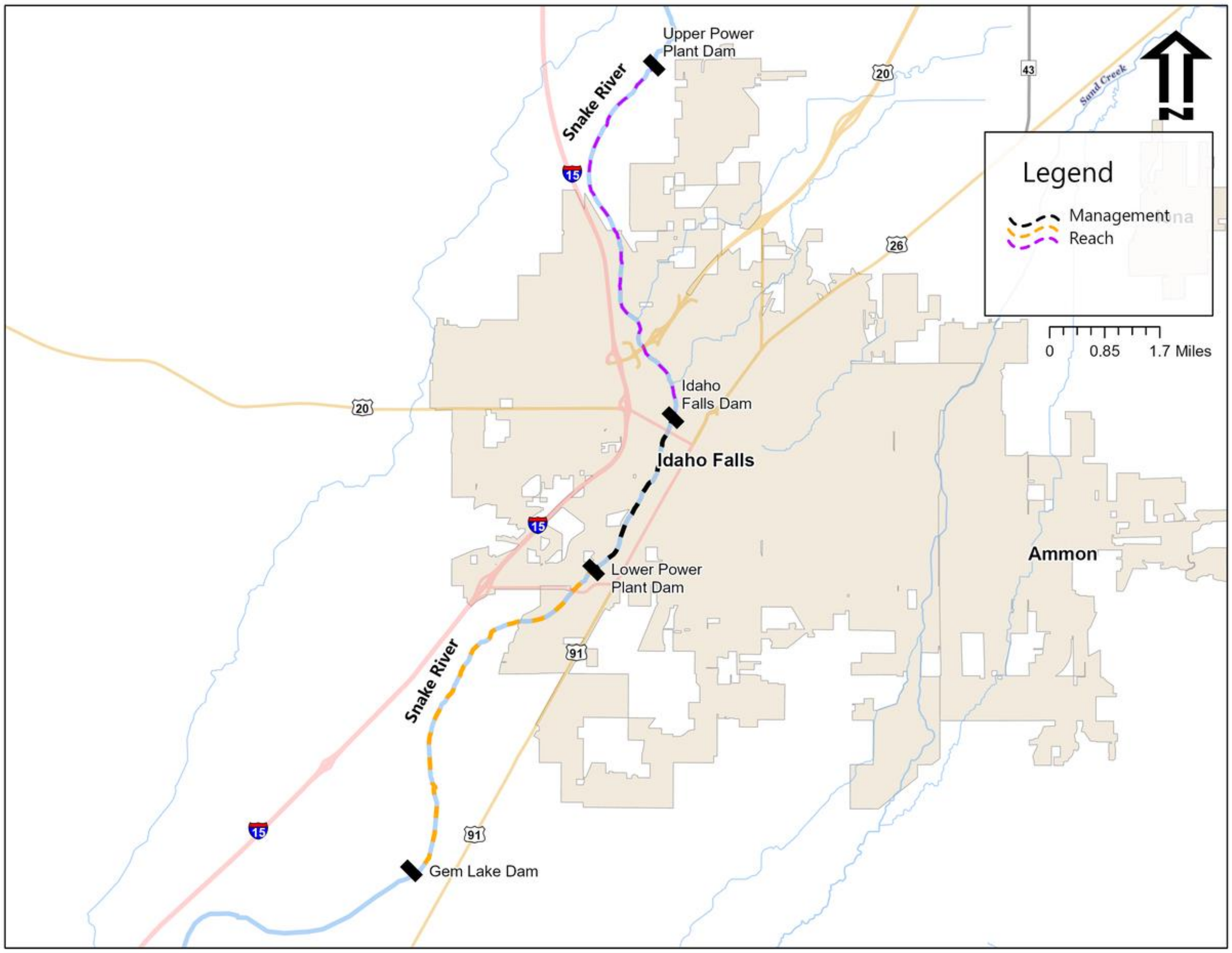

Figure 40. The White Sturgeon reaches on the Snake River in the vicinity of Idaho Falls, ID moving from downstream to upstream including Gem Lake Dam to Lower Power Plant Dam, Lower Power Plant Dam to Idaho Falls Dam, and Idaho Falls Dam to Upper Power Plant Dam reaches.

POPULATION ASSESSMENTS

White Sturgeon fisheries above Shoshone Falls continue to grow in popularity. Angling effort specifically targeting White Sturgeon has increased commensurate to the increase in stocked hatchery fish. Fishery managers recognized that as these fisheries continue to build, it is important to assess the current stocking rates and the potential for providing a harvest opportunity on White Sturgeon in the Upper Snake River. Initial population monitoring for White Sturgeon above Shoshone Falls began in 2021 as a response to public and fishery manager interest in exploring regulation structure change. Objectives for the 2021 sampling were to establish monitoring techniques for these reaches, sample mercury from a variety of White Sturgeon size classes, and begin to build recapture data from previously PIT-tagged hatchery releases to assess entrainment and growth for Upper Snake Reaches.

Relative Abundance Estimate

The 2021 monitoring effort in the Snake River above Shoshone Falls documented survival and movement patters of White Sturgeon above Shoshone Falls. Monitoring was conducted with setlines and hook-and-line sampling. White Sturgeon were captured from nearly all stocked reaches (Figure 41). American Falls Tailwater and Gem Lake Tailwater had the highest catch rates in the upper Snake River reaches regardless of sampling technique.

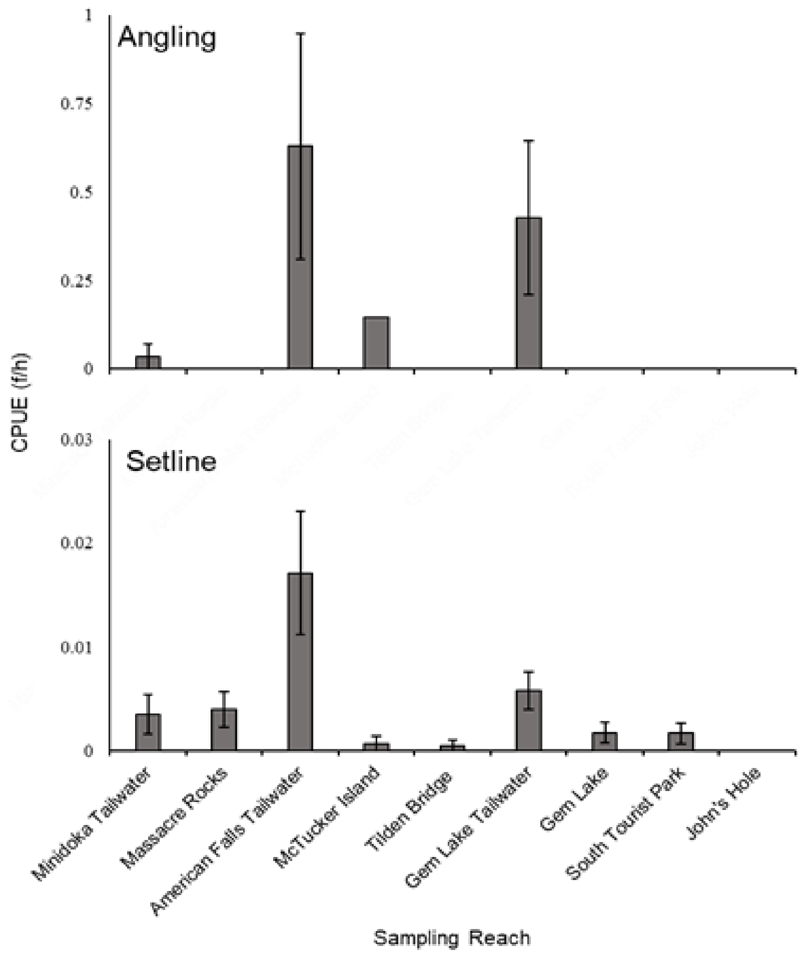

Figure 41. Relative abundances (CPUE ± SE) of White Sturgeon in nine reaches of the upper Snake River, Idaho sampled with setline (bottom panel) and angling (top panel) gears from June – August 2021. Reaches are in left – right order moving upstream in the Snake River.

Growth

White sturgeon captured in 2021 within reaches above Shoshone Falls occupied length classes from 70 to 200 cm (Figure 42). Most of the White Sturgeon that have been stocked above Shoshone Falls have been less than 75 cm (fork length). Length data is available for 1,636 of the 3,192 White Sturgeon stocked above Shoshone Falls between 2007 and 2021. For the 1,614 sturgeon that were less than 75 cm fork length when stocked, the average fork length was 45 cm. Smaller sturgeon were likely not vulnerable to the sampling gear in 2021, so recently stocked fish were not represented.

White Sturgeon captured above Shoshone Falls ranged in size from approximately 50 to 200 cm. Growth calculated from recapture of stocked fish which had been PIT-tagged showed growth in the upper Snake River was intermediate to downstream reaches on the mainstem Snake River; lower growth than the mid-Snake and higher growth than the Hells Canyon reach. In general, reaches around Idaho Falls contained smaller size classes than downstream reaches below American Falls and Massacre Rocks (Figure 42). We have limited data for growth of White Sturgeon in the American Falls to Gem Lake Dam reach. During surveys conducted in 2021, IDFG recaptured 21 White Sturgeon in the tailrace of Gem Dam using set lines (*n* = 11) and hook-and-line methods (*n* = 10). These recaptured fish ranged from 50 to 142 cm FL. Twenty sturgeon had PIT tags, but only 12 had records in the PIT-tag database. Reach-specific stocking records were available for seven of the twelve fish. Of these, one had been stocked in John's Hole in 2014, three had been stocked in the Gem Lake Dam to Lower Power Plant Dam reach (two in 2014 and one in 2016), and the other three had been stocked in into the Gem Lake Dam to American Falls Dam reach (one in 2014 and two in 2020). Growth from time of release for ten of the fish averaged 14 cm/year.

Past data from a citizen-science program was available for the Gem Lake Dam to American Falls Dam reach. In this program, sturgeon anglers in the Gem Lake Dam tailrace section were provided a PIT-tag reader and asked to scan caught fish for PIT tags and record fork lengths. This program yielded growth information for an additional 15 White Sturgeon. The average time between stocking and recapture for these fish was over two years and they averaged 8 cm of growth per year.

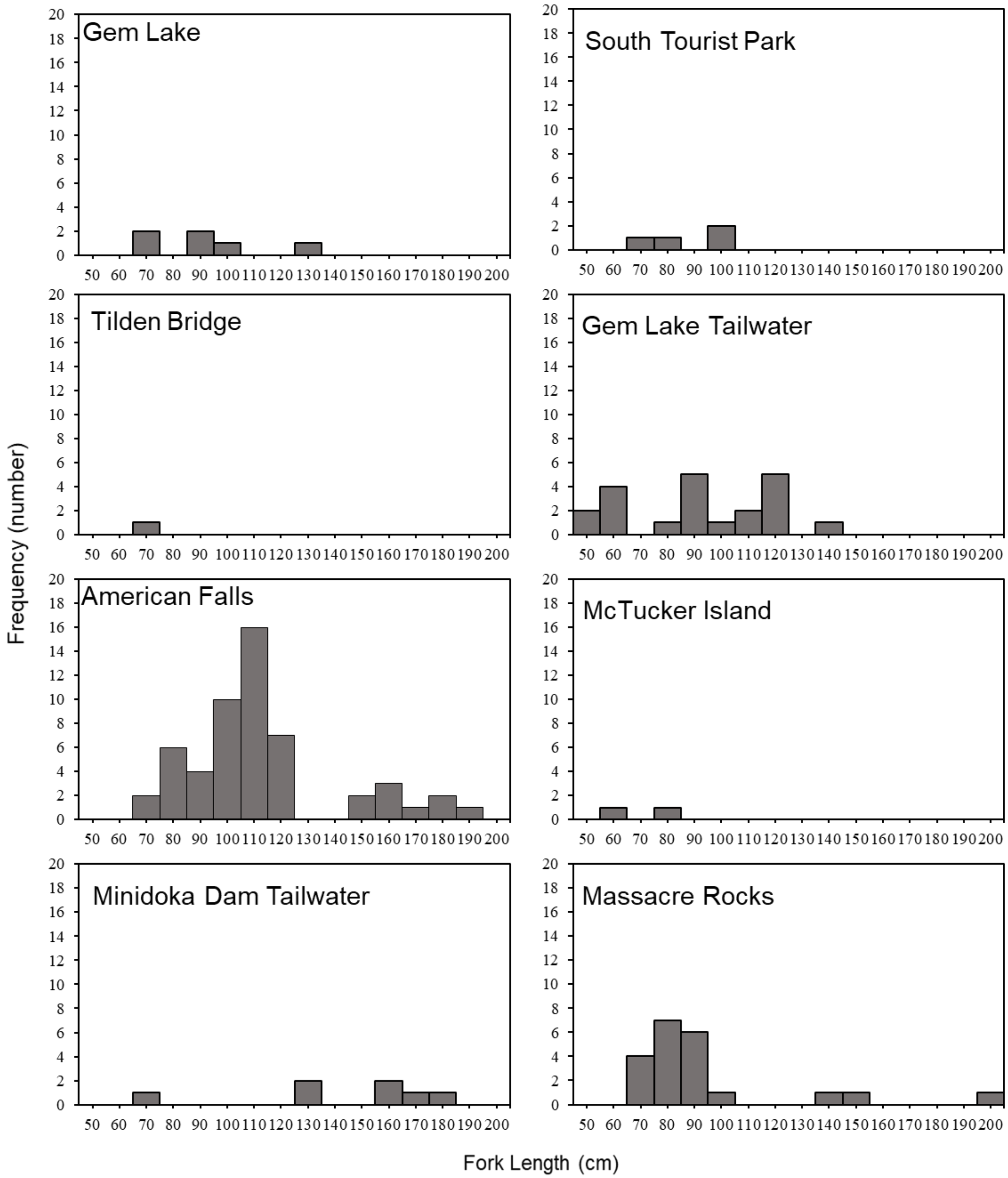

Figure 42. Length-frequency histograms for White Sturgeon captured in eight reaches of the upper Snake River, Idaho from June to August 2021. Reach location is labeled in the upper left corner of each panel.

Movement

The monitoring effort in 2021 recaptured 58 White Sturgeon which had specific location stocking records from their release. Of those recaptures, 86% were within 50 rkm of their stocking location and 14% had traveled over 100 rkm from their stocking location. The majority (78%) of White Sturgeon did not entrain through a dam from stocking to recapture. However, 22% entrained through one, 7% through two, and 3% through three dams between stocking and recapture.

Results from the monitoring effort in 2021 established key baseline information on sampling techniques, movement, and growth of White Sturgeon in the Snake River above Shoshone Falls. This monitoring effort is being expanded into a graduate research project partnering with the University of Idaho to build population dynamics models for these reaches to evaluate potential regulation structure within these fisheries. This data will then be presented to the public to develop any seasonal and limits proposals to present to the Commission.

MANAGEMENT APPROACH

Stocking

The first outside of native range stocking (in Idaho) of White Sturgeon occurred in 1990 (Figure 43). Since then, stocking have occurred intermittently within the reaches above Shoshone Falls with more regular stocking occurring after 2013. A total of 6,565 White Sturgeon have been stocked in these reaches since 1990. Detailed stocking location records are unavailable for early stocking events, therefore total stocking above Shoshone Falls is reported within this plan. Stocking has resulted in popular catch-and-release fisheries, specifically below American Falls and Gem Lake dams. Stocking efforts above Shoshone Falls will be conducted with fish collected as part of the repatriation aquaculture program to reduce genetic concerns associated with downstream passage.

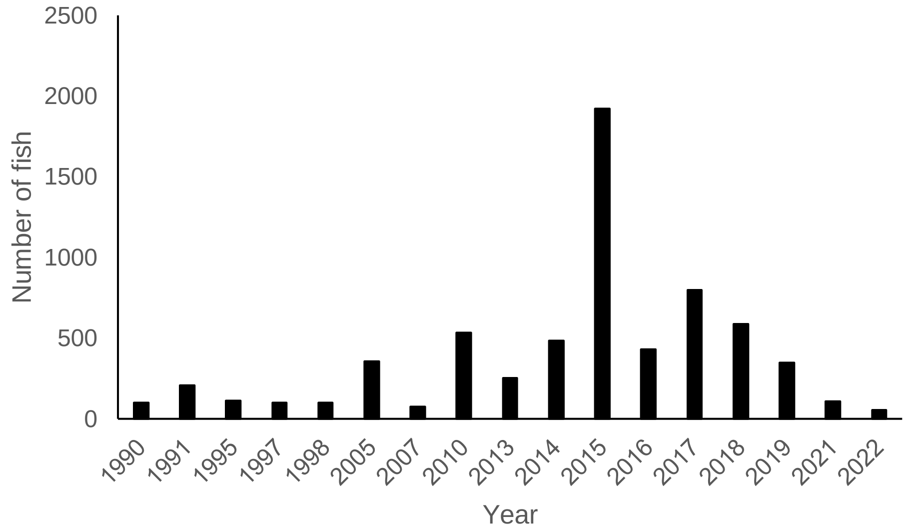

Figure 43. Number of White Sturgeon stocked in reaches above Shoshone Falls from 1990 to 2022.

UNIVERSITY OF IDAHO STUDY

IDFG partnered with the University of Idaho in 2022 to conduct a graduate study of White Sturgeon above Shoshone Falls. The objectives of the project were to evaluate reach abundance, growth, survival, and movement of stocked hatchery sturgeon in the various reaches above Shoshone Falls. The project will also provide additional information to evaluate the potential for natural sturgeon recruitment from these reaches. Findings of the study will be used to inform management decisions surrounding future stocking, stocking prioritization, and evaluate future fishery regulation strategies. IDFG has a desire to explore harvest opportunity in these reaches, this work, along with public input, will help determine how and where that opportunity can be recommended.

FUTURE WORK

- Continue White Sturgeon stocking above Shoshone Falls to provide angling opportunity to the public. Prioritize stocking priority based on findings of the University of Idaho Graduate study.
- Implement stocking strategies and fishery regulation structure for Snake River above Shoshone Falls reaches based on findings of the University of Idaho study.
- Evaluate short-term survival and entrainment of stocked White Sturgeon to inform stocking program.
- If warranted, conduct public meetings and outreach to develop fishing regulation proposals for presentation to the Commission.
- Collect creel data to estimate angler effort and catch.

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LITERATURE CITED

Abatzoglou, J. T., D. E. Rupp, and P. W. Mote. 2014. Seasonal climate variability and change in the Pacific Northwest of the United States. Journal of Climatology 27:2125–2142.

Abatzoglou, J. T., A. M. Marshall, and G.L. Harley. 2021. Observed and Projected Changes in Idaho's Climate. Idaho Climate-Economy Impacts Assessment. James A. & Louise McClure Center for Public Policy Research, University of Idaho. Boise, ID

Auer, N. A. 2004. Conservation. Pages 252-276. In G.T.O. LeBreton, F.W. H. Beamish and R.S. McKinley editors. Sturgeons and Paddlefish of North America. Kluwer Academic Publishers.

Bates, P., J. Chandler, K. Lepla, and K. Steinhorst. 2014. Using mark-recapture data in an individual-based model to evaluate length-at-age differences between two Snake River White Sturgeon (*Acipenser transmontanus* Richardson, 1836) populations in Idaho, USA. Journal of Applied Ichthyology (2014), 1-9.

Bates, P. 2018. Report G. Indexing young-of-year White Sturgeon between Hells Canyon and Lower Granite dams. In: Snake River White Sturgeon Conservation Plan – 2016 Implementation and Reporting. Unpublished Annual Report (2016) to Idaho Power Company, Boise, ID, pp. 148-172.

Bates, P. 2022. Report A. White Sturgeon early life and juvenile indexing in the Snake River between Bliss and C.J. Strike dams. In: Snake River White Sturgeon conservation plan: 2021 implementation and reporting. Unpublished annual report to Idaho Power Company, Boise, ID, p. 9- 42.

Beamesderfer, R. C., T. A. Rien, A. A. Nigro. 1995. Differences in the dynamics and potential production of impounded and unimpounded white sturgeon populations in the lower Columbia River. Transactions of the American Fisheries Society 124: 857–872.

Bentz, B. and K. Lepla. 2009. Population assessment of White Sturgeon in the Snake River between Shoshone Falls and Upper Salmon Falls dams. Report C. In: Snake River White Sturgeon conservation plan: Implementation of measures for White Sturgeon downstream of Shoshone Falls, Bliss and C.J. Strike dams. 2008 Annual Report to Idaho Power Company, Boise, ID. pp 47-90.

Bentz, B. 2010. Report C. Population assessment of White Sturgeon between Upper Salmon Falls and Lower Salmon Falls dams. In: Snake River White Sturgeon conservation plan – Implementation of measures for White Sturgeon in the Snake River between Shoshone Falls and Swan Falls Dam. Unpublished Annual Report to Idaho Power Company, Boise, ID. p. 46-72.

Bentz, B. 2013. Report E. Population survey of White Sturgeon between Lower Salmon Falls and Bliss dams. In: Snake River White Sturgeon Conservation Plan – Implementation of Measures for White Sturgeon in the Shoshone Falls to C.J. Strike and Hells Canyon Reaches of the Snake River. 2011-2012 Unpublished Annual Report to Idaho Power Company, Boise, ID, pp. 118-146.

Bentz, B. 2014. Report C. White Sturgeon population monitoring between Shoshone Falls and Upper Salmon Falls Dam. In: Snake River White Sturgeon conservation plan – 2013 implementation and reporting. Unpublished Annual Report to Idaho Power Company, Boise, ID, pp. 69-107.

Bentz, B. 2015a. Report C. Population survey of White Sturgeon between Hells Canyon and Lower Granite dams. Final completion report. In: Snake River White Sturgeon conservation plan—2014 implementation and reporting. Unpublished Annual Report to Idaho Power Company, Boise, ID, p. 50-94.

Bentz, B. 2015b. Report D. Population survey of White Sturgeon between Upper Salmon Falls and Lower Salmon Falls dams. In: Snake River White Sturgeon Conservation Plan – 2014 Implementation and Reporting. Unpublished Annual Report to Idaho Power Company, Boise, ID, p. 95-122.

Bentz, B. 2018a. Report D. Population Assessment of White Sturgeon between Oxbow and Hells Canyon Dams. In: Snake River white sturgeon conservation plan – 2016 implementation and reporting. Unpublished Annual Report (2016) to Idaho Power Company, Boise, ID, pp78-97.

Bentz, B. 2018b. Report C. Population Assessment of White Sturgeon in the Snake River between C.J. Strike and Swan Falls Dams. In: Snake River White Sturgeon conservation plan – 2016 implementation and reporting. Unpublished Annual Report to Idaho Power Company, Boise, ID, pp 45-77.

Bentz. B., and J. B. Hughes. 2019. Report C. Population assessment of White Sturgeon and side scan sonar evaluation between Lower Salmon Falls and Bliss Dams. In: Snake River White Sturgeon Conservation Plan – 2017 Implementation and Reporting. Unpublished Annual Report to Idaho Power Company, Boise, ID, pp. 60-95.

Bentz, B. and J. Hughes. 2020a. Report C. Population assessment of White Sturgeon and side scan sonar evaluation between Swan Falls and Brownlee dams. In: Snake River White Sturgeon conservation plan: 2018-2019 implementation and reporting. Unpublished Annual Report to Idaho Power Company, Boise. pp. 72-111.

Bentz, B. and J. Hughes. 2020b. Report F. Population assessment of White Sturgeon and side scan sonar evaluation between Shoshone Falls and Upper Salmon Falls Dam. In: Snake River White Sturgeon conservation plan – 2018-2019 implementation and reporting. Unpublished Annual Report to Idaho Power Company, Boise, ID, pp 170-215.

Bentz, B. and J. Hughes. 2020c. Report H. Population assessment of White Sturgeon and side scan sonar evaluation between Upper Salmon Falls and Lower Salmon Falls dams. In: Snake River White Sturgeon conservation plan: 2018- 2019 implementation and reporting. Unpublished Annual Report to Idaho Power Company, Boise, ID, pp 267-299.

Bentz, B and J. B. Hughes 2021. Report C. Population assessment of White Sturgeon between C.J. Strike and Swan Falls dams. In: Snake River White Sturgeon conservation plan – 2020 implementation and reporting. Unpublished Annual Report to Idaho Power Company, Boise, ID, p. 60-96.

Bentz, B. and J. B. Hughes. 2022. Report C. Population assessment of White Sturgeon between Bliss and C.J. Strike dams. In: Snake River White Sturgeon conservation plan – 2021 implementation and reporting. Unpublished Annual Report to Idaho Power Company, Boise, ID, p. 62- 102.

Boucher, M., S. O. McAdam, and J. M. Shrimpton. 2014. The effect of temperature and substrate on the growth, development, and survival of larval White Sturgeon. Aquaculture 430: 139-148.

Bowersox, B. J., J. M. DuPont, R. Tucker, L. B. Barrett and J. A. Lamansky Jr. 2016. Determining the presence of hooks inside white sturgeon using metal detector and portable x-ray technology, North American Journal of Fisheries Management 36: 1045-1052.

Brannon, E., S. Brewer, A. Setter, M. Miller, F. Utter, and W. Hershberger. 1985. Columbia River White Sturgeon early life history

Brink, S. R. and J. A. Chandler. 2000. FERC Additional Information Request #1a: Project flows (Bliss instream flow study). Report to the Federal Energy Regulatory Commission. Idaho Power Company, Boise, Idaho.

Brown, M. E., B. L. Reingold, and S. R. Brink. 2010. Fish Stocking Annual Report 2009. Unpublished Annual Report to Idaho Power Company, Boise, ID.

Burkett, D. P., P. C. Mankin, and G. W. Lewis. 1986. Hook-and-line vulnerability and multiple recapture of Largemouth Bass under a minimum total-length limit of 457 mm. North American Journal of Fisheries Management 6: 109-112.

Caudill, C., Masingale, J., Seaborn, T., Hora, D., Isaak, D. 2021. Sensitivity of Idaho Fishes to Climate Change. Idaho Climate-Economy Impacts Assessment. James A. & Louise McClure Center for Public Policy Research, University of Idaho. Boise, ID.

Chandler, J. A. and K. B. Lepla. 1997. Instream flow evaluations of the Snake River from C.J. Strike Dam to the confluence of the Boise River. Technical Report Appendix E,3,1-C, Idaho Power Company, Boise, Idaho.

Chapman, F. A., J. P. Van Eenennaam, and S. I. Doroshov. 1996. The reproductive condition of White Sturgeon, *Acipenser transmontanus*, in San Francisco Bay, California. Fishery Bulletin 94:628-634.

Clark, G. M. 1998. Water quality in the upper Snake River basin, Idaho and Wyoming, 1992-95 (Vol. 1160). US Geological Survey.

Cochnauer, T. G. 1983. Abundance, distribution, growth and management of White Sturgeon (*Acipenser transmontanus*) in the middle Snake River, Idaho. Doctoral dissertation. University of Idaho, Moscow, Idaho.

Cochnauer, T. G., J. R. Lukens, and F. E. Partridge. 1985. Status of White Sturgeon, *Acipenser transmontanus*, in Idaho. Pages 127-133 in F. P. Bin-kowski and S. I. Doroshov, editors. North American sturgeons: biology and aquaculture potential. Dr. W. Junk, Dordrecht, The Netherlands.

Coon, J.C., R. R. Ringe, T. C. Bjornn. 1977. Abundance, growth and movement of White Sturgeon in the mid-Snake River. Research Technical Completion Report, Project B-026-IDA. Idaho Water Resources Research Institute. University of Idaho, Moscow, Idaho.

Comai, L. 2005. The advantages and disadvantages of being polyploid. Nature Reviews Genetics 6: 836–846.

Counihan, T. D., A. I. Miller, M. G. Mesa and M. J. Parsley. 1998. The Effects of Dissolved Gas Supersaturation on White Sturgeon Larvae. Transactions of the American Fisheries Society 127: 316-322.

Craig, J. A., and R. L. Hacker. 1938. The History and development of the fisheries of the Columbia River. Bulletin No. 32. United States Department of the Interior, Bureau of Fisheries.

Crocker, C. E. and J.J. Cech Jr. 1997. Effects of environmental hypoxia on oxygen consumption rate and swimming activity in juvenile white sturgeon, *Acipenser transmontanus*, in relation to temperature and life intervals. Environmental Biology of Fishes 50: 383-389.

Crump, K. L., and V. L. Trudeau. 2009. Mercury-induced reproductive impairment in fish. Environmental Toxicology and Chemistry 28: 895-907.

DeVore, J. D., James, B. W., Tracey, C. A., Hale, D. A., 1995. Dynamics and potential production of white sturgeon in the unimpounded lower Columbia River. Transactions of the American Fisheries Society 124: 845–856.

DeVore, J. D.; James, B. W.; Gilliland, D. R. 1999: Report B. Evaluate the success of developing and implementing a management plan for white sturgeon in reservoirs between Bonneville and McNary dams in enhancing production and describe the life history and population dynamics of subadult and adult white sturgeon upstream of McNary Dam and downstream from Bonneville Dam. In: Effects of mitigative pressure on productivity of white sturgeon populations in the Columbia River downstream from McNary Dam. D. L. Ward (Ed). Unpublished annual progress report to Bonneville Power Administration, Project No. 198605000. Contract No. DOE/BP-6384-13, Portland, OR, USA, pp. 55–93.

Erhardt, J. M., Tiffan, K. F. 2016. Ecology of nannative Siberian prawn (*Palaemon modestus*) in the lower Snake River, Washington, USA. Aquatic Ecology 50:607–621

Everett, S. R., M. A. Tuell, and J. A. Hesse. 2003. Evaluate potential means of rebuilding sturgeon populations in the Snake River between Lower Granite and Hells Canyon dams. 2002 Annual Report 1997-2002. Report to Bonneville Power Administration. Contract Number 00004046, Project 199700900. Portland, OR.

Gadomski, D. M. and M. J. Parsley. 2005. Laboratory studies on the vulnerability of young White Sturgeon to predation. North American Journal of Fisheries Management. 25: 667-674.

Golder Associates Ltd., 2015. Preliminary analysis of hatchery-reared juvenile white sturgeon population abundance and survival estimates based on 2002-2014 mark-recapture data. Unpublished memo report prepared for BC Hydro, Castlegar, BC, pp. 15.

Gruen, D. 2020. Toxic-Impaired waterbodies on the 303(d) lists in the Columbia River Basin. US Environmental Protection Agency, Region 10. Seattle, WA.

Grunder, S., D. Parrish, and T. Holubetz. 1993. Regional Fisheries Management Investigations. Job Performance Report, Project F-71-R-15, IDFG, Boise, Idaho.

Harrison, J., S. Wells, R. Myers, S. Parkinson, and M. Kasch. 1999. 1999 status report on Brownlee Reservoir water quality and model development. Draft Technical Report. Idaho Power Company, Boise, Idaho.

Hayes, J., Walrond, C., and Deans, C. 1997. Angling pressure on backcountry rivers. Fish and Game New Zealand *16:* 32-9.

Hildebrand, L. C, A. Drauch Schreier, K. Lepla, S. O. McAdam, J. McLellan, M. J. Parsley, V. LO. Paragamian, and S. P. Young. 2016. Status of White Sturgeon (*Acipenser transmontanus Richardson, 1863*) throughout the species range, threats to survival, and prognosis for the future. Journal of Applied Ichthyology 32: 261-312.

Hughes, J. B. 2018. Report A. Juvenile indexing of White Sturgeon in the Snake River between Bliss and C.J. Strike dams. Report A. In: Snake River White Sturgeon conservation plan – 2016 implementation and reporting. Unpublished Annual Report to Idaho Power Company, Boise, ID, pp 1-24.

Hughes, J. B. 2019. Report B. Dual frequency identification sonar (DIDSON) to evaluate potential turbine entrainment of White Sturgeon at C.J. Strike Dam. In: Snake River White Sturgeon Conservation Plan – 2017 Implementation and Reporting. Unpublished Annual Report to Idaho Power Company, Boise, ID, pp. 26-59.

Hughes, J. B. 2020. Report G. White sturgeon recruitment investigations between Hells Canyon and Lower Granite dams. In: Snake River White Sturgeon conservation plan, 2018-2019 implementation and reporting. Unpublished annual report to Idaho Power Company, Boise, ID, pp 216-266.

Hughes, J. B. 2021. Report F. White Sturgeon recruitment investigations between Hells Canyon and Lower Granite dams. In: Snake River White Sturgeon conservation plan – 2020 implementation and reporting. Unpublished Annual Report to Idaho Power Company, Boise, ID, pp 145-185.

Humes, K., Walters, R., Ryu, J., Mahler, R., Woodruff, C. 2021. Water Report. Idaho Climate-Economy Impacts Assessment. James A. & Louise McClure Center for Public Policy Research, University of Idaho. Boise, ID.

Idaho Department of Environmental Quality (IDEQ). 2003. Mid-Snake River/Succor Creek subbasin assessment and total maximum daily load. Boise Regional Office. Idaho Department of Environmental Quality. Boise, ID.

Idaho Department of Environmental Quality (IDEQ). 2004. Mid-Snake River/Succor Creek subbasin assessment and total maximum daily load. Boise Regional Office. Idaho Department of Environmental Quality. Boise, ID.

IDEQ (Idaho Department of Environmental Quality). 2022. Idaho's 2022 integrated report. Boise, ID. Available at:https://www2.deq.idaho.gov/admin/LEIA/api/document/download/16619.

IDFG (IDFG). 2008. Management Plan for the conservation of Snake River White Sturgeon in Idaho. Authored by J. Dillon and S.A. Grunder, Boise.

IDFG (IDFG). 2019. Fisheries Management Plan 2019 – 2024. IDFG, Boise, USA.

IDFG (IDFG). 2023. Idaho state wildlife action plan. 2023 rev. ed. Boise (ID): IDFG. https://idfg.idaho.gov/

Idaho Power Company (IPC). 2013. Snake River White Sturgeon conservation plan – Implementation of measures for White Sturgeon in the Shoshone Falls to C.J. Strike and Hells Canyon reaches of the Snake River. 2011-2012 Annual Report to Idaho Power Company, Boise, ID. 395 pp.

Idaho Power Company (IPC). 2015. Snake River White sturgeon conservation plan, 2015 - 2020 planning and implementation. Unpublished Report to Idaho Power Company, Boise, ID, p. 132.

Idaho Power Company (IPC). 2018. Section 401 water-quality certification application – Hells Canyon Complex FERC No. 1971. Idaho Power Company, Boise, ID, pp. 268

Idaho Power Company (IPC). 2020. Snake River White Sturgeon conservation plan: 2018-2019 implementation and reporting. Idaho Power Company, Boise, ID, pp. 310.

Idaho Power Company (IPC). 2021. Conservation aquaculture plan for White Sturgeon in the middle Snake River, 2021-2025 Implementation. Idaho Power Company, Boise, ID, pp. 146.

Idaho Department of Environmental Quality (IDEQ). 2022. Idaho's 2022 integrated report. Boise, ID. Available at:https://www2.deq.idaho.gov/admin/LEIA/api/document/download/16619 .

Irvine, R. L.; Schmidt, D. C.; Hildebrand, L. R., 2007: Population status of white sturgeon in the lower Columbia River within Canada. Transactions of the American Fisheries Society 136: 1472–1479.

IUCN (World Conservation Union). 1994. Draft IUCN Red List Categories, Version 2.2. Species 21-22:13-24.

Jackson, Z. J., J. J. Gruber, and J. P. Van Eenennaam. 2016. White Sturgeon spawning in the San Joaquin River, California, and effects of water management. Journal of Fish and Wildlife Management 7:171–180. doi: https://doi.org/10.3996/092015-JFWM-092

Jager, H. I., K. Lepla, J. Chandler, and W. Van Winkle. 2001a. A theoretical study of river fragmentation by dams and its effects on White Sturgeon populations. Environmental Biology of Fishes 60: 347-361.

Jager, H. I., W. Van Winkle, J.A. Chandler, K.B. Lepla, P. Bates, and T.D. Counihan. 2001b. A simulation study of factors controlling White Sturgeon recruitment in the Snake River. Pages 127-150 in W. Van Winkle, P.J. Anders, D.H. Secor, and D.A. Dixon, editors. Biology, management, and protection of North American sturgeon. American Fisheries Society, Symposium 28, Bethesda, Maryland.

Jager, H. I., M. J. Parsley, J. J. Cech Jr., R. L. McLaughlin, P. S. Forsythe, R. F. Elliott, B. M. Pracheil. 2016. Reconnecting fragmented sturgeon populations in North American rivers. Fisheries 41: 141-148.

Kliskey, A., J. Abatzoglou, L. Alessa, C. Kolden, D. Hoekema, B. Moore, S. Gilmore, and G. Austin. 2019. Planning for Idaho's waterscapes: A review of historical drivers and outlook for the next 50 years. Environmental Science and Policy 94: 191-201.

Kozfkay, J. R. and J. C. Dillon. 2011. Creel Survey Methods to Assess Catch, Loss, and Capture Frequency of White Sturgeon in the Snake River, Idaho. North American Journal of Fisheries Management 30: 221-229.

Kruse-Malle, G. O. 1993. White sturgeon evaluations in the Snake River. Job performance report. IDFG, Boise, ID. Project F-73-R-15.

Lamansky, J. A., K. A. Meyer, J. M. Dupont, B. J. Bowersox, B. Bentz, and K. B. Lepla. 2017. Deep hooking, landing success and gear loss using inline and offset circle and J hooks when bait fishing for white sturgeon. Fisheries Management and Ecology (25): 100-106.

Lamansky, J. A., K. A. Meyer, B. J. Bowersox, J. M. Dupont, B. Bentz, and K. B. Lepla. 2018a. Incidence, types, and shedding and ingestion times of metallic fishing tackle in the digestive systems of white sturgeon. North American Journal Fisheries Management 38: 1152-1159.

Lamansky, J. A., K. A. Meyer, B. Spaulding, B. J. Jaques, and D. P. Butt. 2018b. Corrosion rates and compression strength of white sturgeon-sized fishing hooks exposed to simulated stomach conditions. North American Journal Fisheries Management 38: 896-902.

Lepla, K. B. 1994. White Sturgeon abundance and associated habitat in Lower Granite Reservoir, Washington. Masters Thesis. University of Idaho, Moscow, Idaho.

Lepla, K. B. and J. A. Chandler. 1997. Status of White Sturgeon in the C.J. Strike reach of the middle Snake River, Idaho. In: Volume 1, Technical appendices for the C.J. Strike Hydroelectric project. Idaho Power Company Technical report E.3.1-B. Idaho Power Company, Boise, Idaho.

Lepla, K. B., J. A. Chandler, and P. Bates. 2001. Status of Snake River White Sturgeon associated with the Hells Canyon Complex. In: Lepla, editor. Chapter 1. Status and habitat use of Snake River White Sturgeon associated with the Hells Canyon Complex. Technical appendices for Hells Canyon Complex Hydroelectric Project, Technical Report E.3.1-6. Idaho Power Company, Boise, Idaho.

Lepla, K. B., J. Anderson, P. Bates. 2002. An assessment of White Sturgeon in the Shoshone Falls – Upper Salmon Falls reach of the Snake River. Idaho Power Company. Boise, Idaho.

Lepla, K. B., P. Bates, and B. Bentz, 2004. Stock assessments of Snake River White Sturgeon below Upper and Lower Salmon Falls Dams. Idaho Power Company, Boise, Idaho.

Lukens J. R. 1981. Snake River sturgeon investigations (Bliss Dam upstream to Shoshone Falls). IDFG, Boise, Idaho.

Lukens, J. R. 1984. Hells Canyon White Sturgeon investigations. Job Performance Report. IDFG, River and Stream Investigations. Project F-73-R-3. IDFG, Boise, Idaho.

Lukens, J. R. 1985. Hells Canyon White Sturgeon investigations. Job Performance Report. IDFG, River and Stream Investigations. Project No. F-73-R-7. IDFG, Boise, Idaho.

McAdam, S.O. 2011. Effects of substrate condition on habitat use and survival by White Sturgeon (*Acipenser transmontanus*) larvae and potential implications for recruitment. Canadian Journal of Fisheries and Aquatic Sciences 68: 812-822.

McCabe, G. T. Jr., R. L. Emmet, and S. A. Hinton. 1993. Feeding ecology of juvenile White Sturgeon (*Acipenser transmontanus*) in the lower Columbia River. Northwest Science 67: 170-180.

McLean, M. F., M. K. Litvak, E. M. Stoddard, S. J. Cook, D. A. Patterson, S. G. Hinch, D. W. Welch, and G. T. Crossin. 2020. Linking environmental factors with reflex action mortality predictors, physiological stress, and post-release movement behavior to evaluate the response of White Sturgeon (*Acipenser transmontanus* Richardson, 1836) to catch-and-release angling. Comparative Biochemistry and Physiology Part A 240: 110618.

Miller, A. I. and Beckman, L. G. 1996. First Record of Predation on White Sturgeon Eggs by Sympatric Fishes. Transactions of the American Fisheries Society 125: 338-340.

Muir, W. D. and G. T. Jr. McCabe. 2000. Diet of first-feeding larval and young of the year White Sturgeon in the lower Columbia River. Northwest Science 74: 25-33.

Myers, R., J. Harrison, S. K. Parkinson, B. Hoelscher, J. Naymik, and S. E. Parkinson. 2002. Pollutant transport and processing in the Hells Canyon Complex. In: Technical appendices for new license application: Hells Canyon Hydroelectric Project. Idaho Power. Boise, ID. Technical Report E.2.2-2.

Niklitschek, D. J. and D. H. Secor. 2009. Dissolved oxygen, temperature and salinity effects on the ecophysiology and survival of juvenile Atlantic sturgeon in estuarine waters: I. Laboratory results. Journal of Experimental Marine Biology and Ecology 381: 150-160.

Nez Perce Tribe (NPT). 2005. White Sturgeon Management Plan in the Snake River between Lower Granite and Hells Canyon Dams. 1997-2005 Final Report, Project No. 199700900, BPA Report DOE/BP-00004046-3.

O'Connor, B. L. 2021. Water temperature trends in the Columbia River Basin. USACE Portland District.

Pacific States Marine Fisheries Commission (PSMFC). 1992. White Sturgeon management framework plan. Prepared by the White Sturgeon Planning Committee, PSMFC, Portland, OR. 201 p.

Paragamian, V. L. and V. D. Wakkinen. 2002. Temporal distribution of Kootenai River White Sturgeon spawning events and the effect of flow and temperature. Journal of Applied Ichthyology 18: 542-549.

Paragamian, V. L.; Beamesderfer, R. C. P.; Ireland, S. C., 2005: Status, population dynamics, and future prospects of the endangered Kootenai River White Sturgeon population with and without hatchery intervention. Transactions of the American Fisheries Society 134, 518–532.

Parsley, M. J.; Beckman, L. G., 1994. White sturgeon spawning and rearing habitat in the lower Columbia River. North American Journal of Fisheries Management 14: 812–827.

Reed D. H. and R. Frankham. 2003. Correlation between fitness and genetic diversity. Conservation Biology 17, 230–237.

Reid, W., W. H. Goodnight, and B. B. Bowler. 1973. Survey of fish populations in the Snake River above Brownlee Reservoir. IDFG, Boise, ID. Federal Aid to Fish Restoration Project F-63-R-2.

Reid, W. W., and B. Mabbot. 1987. Regional fisheries management investigations: Region 3 (Boise) river and stream investigations. Unpublished technical report to IDFG, River and Stream Investigations. Federal Aid to Fish Restoration Project F-71-R-11, Boise, ID.

Saffron, I., 2004. The decline of the North American species. In: *Sturgeons and paddlefish of North America*. G. T. O. LeBreton, F. W. H. Beamish and R. S. McKinley (Eds.) Kluwer Academic Publishers, Dordrecht, pp. 1– 21.

Scarnecchia, D. L. and J. D. Schooley. 2022. Trophies, technology, and timescape in fisheries management, as exemplified through Oklahoma’s world record Paddlefish *Polydon spathula*. Fisheries 47: 381-394.

Schill, D. J., J. S. Griffith and R. E. Gresswell. 1986. Hooking Mortality of Cutthroat Trout in a Catch-and-Release Segment of the Yellowstone River, Yellowstone National Park, North American Journal of Fisheries Management, 6: 226-232.

Schreier, A., S. Brandl, and B. May. 2013. Snake River White Sturgeon Genetic Management Plan. Final report to Idaho Power Company. Boise, ID. 60 p.

Schreier, A., Coen, A., and D. Myers. 2020. Genetic Monitoring of Snake River White Sturgeon. A technical report to Idaho Power Company. Boise, ID.

Secor, D. H. and E. J. Niklitschek. 2001. Hypoxia and sturgeons. Report to the Chesapeake Bay Program Dissolved Oxygen Criteria Team. Solomons, MD.

Semakula, S. N., and P. A. Larkin. 1968. Age, growth, food and yield of White Sturgeon (*Acipenser transmontanus*) of the Fraser River, British Columbia. Fisheries Research Board of Canada 25(12):2589-2602.

Shade, M., O. P. Langness, and L. B. Heironimus. 2020. White Sturgeon mitigation and restoration in the Columbia and Snake rivers upstream from Bonneville Dam, Report E. in D. L. Ward, editor. Effects of mitigative measures on productivity of White Sturgeon populations in the Columbia River downstream from McNary Dam, and determine the status and habitat requirements of White Sturgeon populations in the Columbia and Snake Rivers upstream from McNary Dam. Annual Progress report 2019 to Bonneville Power Administration, Project 86-50, Portland, Oregon.

Sullivan, A. B., Jager, H. I., and R. Myers. 2003. Modeling White Sturgeon movement in a reservoir: the effect of water quality and sturgeon density. Ecological Modeling 167: 97-114.

Tiffan, K. F., J. M. Erhardt, and B. K. Bickford. 2017a. Ecology of the Opossum Shrimp (*Neomysis mercedis*) in a lower Snake River reservoir, Washington. Northwest Science 91:124–139.

Tiffan, K. F., J. M. Erhardt, T. N. Rhodes, and R. J. Hemingway. 2017b. Ecology of the Sand Roller (*Percopsis transmontana*) in A lower Snake River reservoir, Washington. Northwestern Naturalist 98(3):203-214.

U.S. Fish and Wildlife Service (USFWS). 2019. Revised Recovery Plan for the Kootenai River Distinct Population Segment of the White Sturgeon. U.S. Fish and Wildlife Service, Portland, Oregon. vi + 35 pp.

Wang, Y. L.; Binkowski, F. P.; Doroshov, S. I. 1985: Effect of temperature on early development of white and lake sturgeon, *Acipenser transmontanus* and *A. fulvescens*. In: North American sturgeons: biology and aquaculture potential. F. P. Binkowski and S. I. Doroshov (Eds). W. Junk Publishers (member of Kluwer Academic Publisher Group), Dordrecht, The Netherlands, pp. 43–50, 163 pp.

Webb, M. A. H, G. W. Feist, M. S. Fitzpatrick, E. P. Foster, C. B. Schreck, M. Plumlee, C. Wong, and D. T. Gundersen. 2006. Mercury concentrations in Gonad, liver, and muscle of White Sturgeon *Acipenser transmontansus* in the Lower Columbia River. Archives of Environmental Contamination and Toxicology 50:443-451.

Welsh, T. L. and W. W. Reid. 1971. Hells Canyon Fisheries Investigation 1970 Annual Completion Report. IDFG, Boise, ID

White, S. L., D. A. Fox, T. Beridze, S. K. Bolden, R. L. Johnson, T. F. Savoy, F. Scheele, A. D. Schreier, and D. C. Kazyak. 2023. Decades of global sturgeon conservation efforts are threatened by an expanding captive culture industry. Fisheries 48:54-61.

Wydoski, R. S., and R. R. Whitney. 2003: Inland fishes of Washington, 2nd edn. University of Washington Press, Seattle, WA, USA, 384 p.

APPENDICES

Appendix A. Mean annual survival rates (Phi) of White Sturgeon populations groups by reach and size class (courtesy of Idaho Power Company).

Reach	Population Group	Phi	SE	95% Confidence Interval	
				Lower	Upper
Shoshone Falls	All WS	0.95	0.006	0.94	0.96
	Juvenile	0.98	0.014	0.92	0.99
	Sub-adult	0.95	0.007	0.93	0.96
	Adult	0.95	0.018	0.90	0.97
Upper Salmon Falls	All WS	0.94	0.048	0.74	0.99
	Juvenile	0.96	0.064	0.48	1.00
	Sub-adult	0.94	0.040	0.80	0.98
	Adult	–	–	–	–
Lower Salmon Falls	All WS	0.93	0.027	0.86	0.97
	Juvenile	0.86	0.057	0.71	0.94
	Sub-adult	0.90	0.034	0.81	0.95
	Adult	0.97	0.028	0.82	1.00
Bliss	All WS	0.96	0.006	0.94	0.97
	Juvenile	0.94	0.009	0.92	0.95
	Sub-adult	0.95	0.009	0.93	0.96
	Adult	0.98	0.008	0.96	0.99
C.J. Strike	All WS	0.90	0.005	0.89	0.91
	Juvenile	0.87	0.009	0.85	0.89
	Sub-adult	0.92	0.008	0.90	0.93
	Adult	0.92	0.010	0.89	0.94
Swan Falls	All WS	0.75	0.011	0.73	0.77
	Juvenile	0.73	0.012	0.70	0.75
	Sub-adult	0.74	0.045	0.64	0.82
	Adult	0.93	0.018	0.88	0.95

Appendix B. Mean frequency of metal detected within Snake River White Sturgeon intestinal tracts by river reach and size class, with corresponding mean relative weight (W_r). Data were collected either during population estimates by IPC or targeted research by IDFG.

Reach	Survey year	Overall	Juvenile	Sub-adult	Adult	Sample size	Mean W_r	Adult W_r
Shoshone Falls	2018	13%	0	14%	16%	179	83	84
Upper Salmon[1]	2019	12.50%	-	-	0	15	93	86
Lower Salmon[2]	2022	49%	33%	50%	52%	47	80	78
Bliss[3]	2021	11.1%	0.0%	7.1%	14.6%	405	87	83
C.J. Strike[4]	2020	27%	7%	23%	42%	74	88	83
Swan Falls	2019	33%	10%	-	43%	52	77	73
Hells Canyon[5]	2010 – 2016 (Lamansky 2018)	21%	10%	-	36%	2077	86-88	
Hells Canyon	2014 (IPC pop est)	15%	5%	16%	33%	-	88	-

[1] Down from 30% in 2014, small sample size
[2] 58% upstream of the Malad River
[3] 23% in upper reaches
[4] 34% above Grandview Bridge
[5] 45% of fish 150-200 cm