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March 22, 2022

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
Mail Code: DHAC, PJ-12
888 First Street, N.E.
Washington, D.C. 20426

**RE: Priest Rapids Hydroelectric Project No. 2114-192
License Compliance Filing – Article 401(a)(11) – 2021 White Sturgeon Management Plan Annual Report**

Dear Secretary Bose,

Please find enclosed Public Utility District No. 2 of Grant County, Washington (Grant PUD) 2021 White Sturgeon Management Plan (WSMP) Annual Report consistent with the requirements of Article 401(a)(11) of the Priest Rapids Project License[1] and the Washington State Department of Ecology (Ecology) 401 Water Quality Water Quality Certification Condition of 6.2(5)(b) and 6.2(5)(d) for the Priest Rapids Project (Project).

The study objectives and tasks completed under the 2021 M&E program (FERC License Year 14) were as follows:

1). Due to COVID-19, Grant PUD and members of the PRFF agreed that collection of adult broodstock could not proceed in 2020 as maintaining effective social distancing during the capture and transport of broodstock was not feasible. In the absence of 2020 brood year (BY) juveniles for release in 2021, the PRFF agreed to reduce the 2019 BY release size in 2020 and retain a portion of these fish for release in 2021. As such, the 2021 release would be less than the stocking targets previously approved by the PRFF as outlined in the Priest Rapids White Sturgeon Stocking Statement of Agreement (SOA) dated March 11, 2016. As part of the 2021 juvenile release, a tagging, marking, and release plan was developed and implemented.

2). Collect broodstock from John Day reservoir downstream of McNary Dam. This work was conducted directly by Grant PUD with coordination and data collection conducted by Blue Leaf Environmental (BLE). A summary of 2021 broodstock collection efforts is provided in Appendix A.

[1] 123 FERC ¶ 61,049 (2008)

3). Conduct an adult White Sturgeon capture-recapture assessment to estimate survival rate and population abundance of resident adult wild fish in the PRPA. This study component also assessed the population of adult and sub-adult hatchery sturgeon, originally released into the Rock Island Reservoir by the Columbia River Inter-Tribal Fish Commission (CRITFC) in 2003 (2002BY), and that subsequently moved downstream into the PRPA. After initial assessments conducted in 2010 and 2012, ongoing assessments under the M&E program were conducted in 2015 and 2018 and are scheduled to be conducted every 3 years moving forward.

4). Conduct a juvenile White Sturgeon capture and recapture program in September to estimate survival rate and the population abundance of hatchery juvenile sturgeon released to date. These data are needed to inform future annual release numbers in response to brood year specific abundance and survival estimates. Baited small-hook set line gear have been used since 2014 to capture hatchery juvenile White Sturgeon in the PRPA to estimate their survival and abundance (Golder 2015–2021). Sampling methods were standardized in 2016 and the same methodology was used in all subsequent years.

On February 9, 2022, Grant PUD prepared and disseminated the draft 2021 WSMP Annual Report for a thirty day comment period to members of the PRFF, which includes Washington Department of Ecology (WDOE), U.S. Fish & Wildlife Service (USFWS), Washington Department of Fish & Wildlife (WDFW), Colville Confederated Tribes (CCT), Yakama Nation, the Columbia River Inter-Tribal Fish Commission, Bureau of Indian Affairs, Wanapum Indians, and the Confederated Tribes of the Umatilla Indian Reservation. Comments were received from the CCT (Appendix B) and Grant PUD's responses are in Appendix C. On March 16, 2022, WDOE approved the 2021 WSMP Annual Report. (Appendix D).

FERC staff with any questions should contact Tom Dresser at tdresse@gcpud.org or 509-797-5182.

Sincerely,

Shannon Lowry
License Compliance and Lands Services Manager

CC: Breean Zimmerman – Ecology
Priest Rapids Fish Forum

2021
White Sturgeon Management Plan
Annual Report

Priest Rapids Hydroelectric Project (FERC No. 2114)

Prepared for:

Public Utility District No.2 of Grant County
P.O. Box 878
Ephrata, WA 98823

Prepared by:

Golder Associates Ltd.
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March 2022

Thanks are extended to our contributors in this project as follows:

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Paul Grutter	Golder Associates Ltd.
Sima Usvyatsov	Golder Associates Ltd.
Dustin Ford	Golder Associates Ltd.
David Roscoe	Golder Associates Ltd.
Corey Wright	Blue Leaf Environmental Inc.

We wish to specifically acknowledge and thank Mike Clement and his staff for coordinating and fabricating the adult and juvenile White Sturgeon sampling gear used in this study.

List of Abbreviations

401 Certification	Washington Department of Ecology Section 401 Water Quality Certification for the Priest Rapids Project
BY	Brood Year
Chelan PUD	Public Utility District No. 1 of Chelan County, Washington
CPUE	Catch-Per-Unit-Effort
CRITFC	Columbia River Intertribal Fisheries Commission
CBH	Columbia Basin Hatchery
Ep	Proportion of Positive Catch
FERC	Federal Energy Regulatory Commission
FL	Fork Length
Grant PUD	Public Utility District No. 2 of Grant County, Washington
GRTS	Generalized Random-Tessellation Stratified
YNSH	Yakama Nation Sturgeon Hatchery
M&E	Monitoring and Evaluation
PIT	Passive Integrated Transponder
PRPA	Priest Rapids Project area (Project area)
PRFF	Priest Rapids Fish Forum
PTAGIS	PIT-tag Information System
RISFWC	Rock Island Forebay Waterbird Colony
RM	River Mile
SOA	Statement of Agreement
UCWSRI	Upper Columbia White Sturgeon Recovery Initiative
UTM	Universal Transverse Mercator
WSMP	White Sturgeon Management Plan

Executive Summary

Wanapum Dam and Priest Rapids Dam are located in the mid-Columbia River region in the Priest Rapids Project Area (PRPA or the "Project area") and are owned by Public Utility District No. 2 of Grant County, Washington (Grant PUD). Article 401 of the FERC license requires Grant PUD to conduct a Monitoring and Evaluation (M&E) program to evaluate the effect of Project operations on White Sturgeon (*Acipenser transmontanus*) populations within the PRPA. The study objectives and tasks completed under the 2021 M&E program (FERC License Year 14) in the PRPA included the following study components; 1) tagging, marking, and release of the remaining 2019 Brood Year (2019BYb) hatchery juvenile White Sturgeon, 2) adult White Sturgeon population indexing to estimate survival rate and the population abundance of adult sturgeon, and 3) juvenile White Sturgeon population indexing to estimate survival rate and the population abundance of hatchery juvenile sturgeon.

Prior to tagging, the 2019BYb were tested individually for spontaneous autopolyploidy and 16 fish with the syndrome were identified. The remaining 2019BYb fish without spontaneous autopolyploidy (n = 1485 fish) were tagged from April 6 to 8 and were released on April 20. An alternative release strategy for Priest Rapids reservoir was implemented in 2021 to address risk of possible density dependent growth of juvenile fish released in the Wanapum Dam tailrace area where fish densities are high compared to other areas in the reservoir. Under the new release strategy, fish were released at the Priest Rapids Recreation Area boat launch (RM400.3) in Priest Rapids reservoir (n = 549 fish; 38%), and at the Vantage boat launch (RM420.6) in Wanapum reservoir (n = 936 fish; 62%). Broodstock collection was successfully completed in May 2021 to produce a 2021BY based on a 6Fx6M spawning matrix using fish captured in John Day reservoir.

Capture and recapture sessions during the Adult White Sturgeon indexing program were conducted from August 16 to September 18. In total, 443 fish were captured, with juvenile hatchery fish contributing most of the total catch (415 of the 443 fish). The remainder of the fish were adult White Sturgeon and these consisted of 8 wild fish (7 adults; 1 subadult) and 20 2002BY adults. The 2002BY were hatchery fish released by the Columbia Inter-Tribal Fish Commission (CRITFC) in Rock Island reservoir upstream of the PRPA in 2003. The 2002BY captured were mature and both ripe female and male fish of this brood year were identified. Combined with existing adult indexing data from 2010, 2012, 2015, 2018, and 2021, data were sufficient to obtain POPAN population estimates for three groups: the 2002BY, 2010BY–2019BY, and wild fish. Other metrics, like catch proportion, length-frequency, CPUE, and Ep estimates, were calculated for each brood year to infer differences in survival and abundance among groups and to support the POPAN population model results. Adult capture data were used to assess differences in the catchability of hatchery fish by brood year between the small-hook juvenile set line gear and the adult capture set line gear. With completion of the second adult indexing study since the 2002BY removal effort from 2015 to 2018, the 2021 POPAN model population estimates of wild fish in Wanapum reservoir declined from 853 fish (95% CIs = 486–1,496) in 2015, immediately prior to the removal effort, to 100 fish (95% CIs = 41–242) in 2018, to 82 fish (95% CIs = 31–218) in 2021. Similarly, in Priest Rapids reservoir, where the wild fish population historically has been low, the wild population declined from 47 fish (95% CIs = 27–82) in 2015, to 12 fish (95% CIs = 5–30) in 2018, to 12 fish (95% CIs = 4–31) in 2021. The loss of a large proportion of the wild fish population in the PRPA was likely a consequence of the 2002BY removal effort.

Juvenile White Sturgeon indexing conducted in 2021 captured 924 fish and exceeded all previous annual catches. The juvenile White Sturgeon Cormack-Jolly-Seber (CJS) population model was revised to calculate survival probability estimates and recapture probabilities by brood year to estimate total White Sturgeon populations for each reservoir by calendar year. Other metrics, like catch proportion, length-frequency, CPUE, and Ep estimates, were calculated for each brood year to infer differences in survival and abundance among groups and to support the CJS population model results. Two separate survival estimates were generated for the 2010BY to account for loss of individuals taken as bycatch during the 2015-2018 2002BY removal effort. To account for the reduction in captures of larger fish as fish recruited away from the juvenile gear, the recapture rate was allowed to vary with age. This specification of the model accounted for change in recapture rates between brood years, and informed the model, so that survival of older brood years was not artificially deflated due to fish recruiting away from the gear. Estimates of hatchery fish abundance in 2021 in Wanapum reservoir was 8,992 (95% CI = 7,209–10,775) or 32% of total hatchery releases to date (28,489 fish). In Priest Rapids reservoir, the 2021 hatchery fish abundance estimate was 3,313 (95% CI = 2,493–4,132) or 27% of total hatchery releases to date (12,256 fish). Future juvenile indexing studies will continue to address sample gear bias by assessing the size selectivity of the juvenile sampling gear.

Mean annual growth rates recorded in 2021 for each hatchery brood year were comparable to rates recorded during previous study years. In 2021, higher growth rates were recorded in Wanapum reservoir than in Priest Rapids reservoir. Lower growth rates were evident for individuals of brood years that resided in the upper sections of each reservoir and was assumed to relate to higher energetic cost and possibly to localized density dependent growth. Overall, density dependent growth of fish was not evident in Wanapum reservoir in 2021. In Priest Rapids reservoir, growth was slower for fish older than age-6; however, it was unclear if the reduce growth rate was density dependent and additional growth data are required.

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1.0 Introduction

Wanapum Dam and Priest Rapids Dam are located in the mid-Columbia River region in the Priest Rapids Project area (PRPA or the "Project area") and are owned by Public Utility District No. 2 of Grant County, Washington (Grant PUD). On April 17, 2008, the Federal Energy Regulatory Commission (FERC) issued Grant PUD a 44-year license (FERC No. 2114) to operate Wanapum and Priest Rapids dams as part of the license for the Priest Rapids Project (the Project). As part of the Washington Department of Ecology Section 401 Water Quality Certification for the Project (401 Certification), Article 401 of the FERC license requires Grant PUD to conduct a Monitoring and Evaluation (M&E) program to evaluate the effect of Project operations on White Sturgeon (*Acipenser transmontanus*) populations within the PRPA.

In response to the FERC license requirement, Grant PUD developed, in consultation with the Priest Rapids Fish Forum (PRFF), a White Sturgeon Management Plan (WSMP), with the overarching goal to restore and maintain White Sturgeon populations in the PRPA. Restoration of the White Sturgeon population was to be achieved primarily through conservation aquaculture and the annual release of hatchery-raised juvenile White Sturgeon into the Project area over a 25-year supplementation period, with the goal of creating a self-sustaining and genetically diverse population to levels commensurate with the available aquatic habitat in the PRPA. Under the WSMP, the main objectives of the studies conducted under the M&E program were to assess the following: 1) the effectiveness of the supplementation program; 2) the carrying capacity of habitat in the Project area; and 3) the level of natural recruitment of White Sturgeon in the Project area. On an annual basis, the M&E program study results are reviewed by members of the PRFF who, through consensus, provide recommendations to modify and align the M&E program with long-term recovery objectives for the PRPA and other White Sturgeon recovery initiatives in the Columbia River Basin.

Due to the COVID-19 pandemic, COVID-19 mitigation plans were included as part of the health and safety protocols for each M&E study component. The objective of the COVID-19 mitigation plans was to reduce the risk of COVID-19 transmission and still allow each component of the 2021 M&E program to proceed. The study objectives and tasks completed under the 2021 M&E program (FERC License Year 14) were as follows:

1). Due to COVID-19, Grant PUD and members of the PRFF agreed that collection of adult broodstock could not proceed in 2020 as maintaining effective social distancing during the capture and transport of broodstock was not feasible. In the absence of 2020 brood year (BY) juveniles for release in 2021, the PRFF agreed to reduce the 2019BY release size in 2020 and retain a portion of these fish for release in 2021. As such, the 2021 release would be less than the stocking targets previously approved by the PRFF as outlined in the Priest Rapids White Sturgeon Stocking Statement of Agreement (SOA) dated March 11, 2016. As part of the 2021 juvenile release, a tagging, marking, and release plan was developed and implemented.

2). Collect broodstock from John Day reservoir downstream of McNary Dam. This work was conducted directly by Grant PUD with coordination and data collection conducted by Blue Leaf Environmental (BLE). A summary of 2021 broodstock collection efforts is provided in Appendix A.

3). Conduct an adult White Sturgeon capture-recapture assessment to estimate survival rate and population abundance of resident adult wild fish in the PRPA. This study component also assessed the population of adult and sub-adult hatchery sturgeon, originally released into the Rock Island Reservoir by the Columbia River Inter-Tribal Fish Commission (CRITFC) in 2003 (2002BY), and that subsequently moved downstream into the PRPA. After initial assessments conducted in 2010 and 2012, ongoing assessments under the M&E program were conducted in 2015 and 2018 and are scheduled to be conducted every 3 years moving forward.

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The following introductory sections summarize the approach and results of the M&E program components conducted in 2021 and the implication of the results in context with Grant PUD management objectives for the White Sturgeon population within the PRPA.

The Priest Rapids Project Area

The PRPA is approximately 99 km long (61.5 miles), with the upstream boundary defined by Rock Island Dam (River Mile [RM] 453.0 and the downstream boundary defined by Vernita Bar (RM392.0) downstream of Priest Rapids Dam (Figure 1). Wanapum Dam is located at RM416.0. For the purpose of study design and data analysis, each reservoir was divided into “lower”, “middle”, and “upper” sections. These section boundaries were determined based on coarse approximations of hydraulic and physical characteristics common to each section, which included water velocity, channel confinement, and the amount of inundated area beyond the original river channel confinement after impoundment. The sections represented the transition from lotic conditions in the upper reservoir section, a transitional middle section where water velocity is reduced, to lentic conditions in the lower reservoir section, where water velocity is low and other environmental factors, such as wind velocity, wind direction, and fetch (reservoir length) become more relevant and have a substantial effect on ecosystem processes.

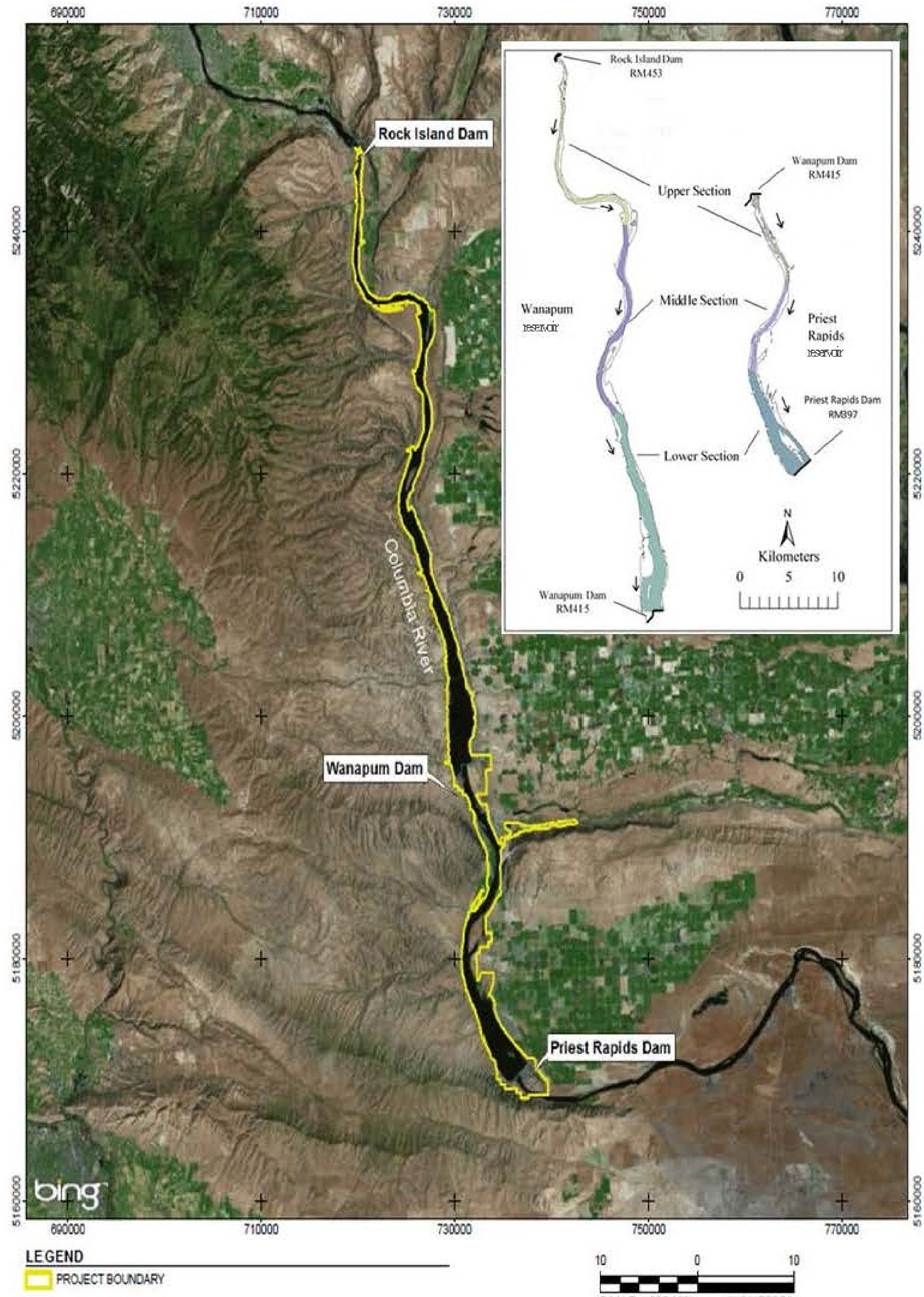

Figure 1 **The Priest Rapids Project area. Inset shows the location of the upper, middle, and lower sections in the Priest Rapids and Wanapum reservoirs.**

1.1 Consultation

Pursuant to the FERC reporting requirements, Grant PUD provided a complete draft of the 2021 WSMP Annual Report to the PRFF on February 9, 2022 for review. Written comments were received from Colville Confederated Tribes on February 18, 2022. Washington Department of Ecology approved the 2021 WSMP Annual Report on March 16, 2022. A summary of written comments from the PRFF, as received by Grant PUD on the draft 2021 WSMP Annual Report, have been compiled along with responses from Grant PUD (Appendix C).

2.0 Methods

Study methods used in 2021 were similar to previous studies (Golder 2016, 2021), with similar approaches and levels of effort applied for the study components common to each year, which included hatchery juvenile White Sturgeon tagging and release, adult White Sturgeon population indexing, and juvenile White Sturgeon population indexing.

The following sections provide general descriptions of methods used and details where the 2021 methodology deviated from previous studies and where new methods or approaches were applied.

2.1 Environmental Variables

2.1.1 Discharge and Temperature

Total river discharge and temperature data recorded in the tailwater of Rock Island Dam were used to document these environmental variables within the PRPA during each study component. Mean hourly total river discharge and water temperature data from January 1 to December 31, 2021 were obtained from the Columbia River Data Access in Real Time webpage (DART 2021).

2.2 2019BY Rearing and Marking, and Release

Approximate 2,000 2019BY juvenile hatchery White Sturgeon were reared at the Yakama Nation Sturgeon Hatchery (YNSH) for release in 2021 as part of the modified release strategy approved by the PRFF due to pandemic-related disruptions of broodstock collection in 2020 (Section 1.0). The 2021 release strategy was based on the SOA prescription, with 62% (1,240) released in Wanapum reservoir and the remaining 38% (760 fish) released in Priest Rapids reservoir.

The 2019BY juvenile White Sturgeon were the progeny of a partial 5Fx5M spawning matrix conducted on June 14, 2019 at YNSH. Four females were crossed with five males to produce 20 genetic crosses (4 unique crosses; 16 half-sibling crosses). The fifth female yielded only enough eggs to produce a full 1x3 spawning matrix that resulted in three genetic crosses and a partial fourth cross with a fourth male. In total, 24 genetic crosses (4 unique crosses and 20 half-sibling crosses) were produced for the 2020 and 2021 supplementation releases. The progeny of each maternal family was kept in separate rearing pens. In 2020, preliminary screening identified a low-level presence of spontaneous autopolyploidy in four of the five maternal families. Individuals from a single maternal family that tested entirely negative for spontaneous autopolyploidy were released in 2020. The remaining families were retained for release in 2021 and when testing of individual fish for spontaneous autopolyploidy with a Coulter counter would be an option. In this report, fish released in 2020 were designated 2019BYa; fish released in 2021 were designated as 2019BYb.

Tagging and marking of the remaining 2019BYb held at YNSH was conducted by Grant PUD biologists, YNSH staff, and Blue Leaf Environmental (BLE) staff. Prior to tagging, a Coulter counter was used to test each individual fish for the presence of spontaneous autopolyploidy. Blood samples extracted from the caudal vein from each fish were obtained, prepared, and tested with the Coulter counter to determine if the fish was 8N (i.e., normal genetic composition) or either 10N or 12N (autopolyploidy). Only fish that tested negative for spontaneous autopolyploidy were processed. Approximately equal numbers from four of the five maternal family crosses were tested and tagged during the 2021 release. All 2019BY White Sturgeon received a 12.5 mm, 134.2 kHz ISO full-duplex passive integrated transponder (PIT) tag (Biomark®) inserted on the left side of the fish at the base of the 4th dorsal scute, with the tag oriented with the body axis towards the head of the fish. Each tagged fish was externally marked as direct gamete origin hatchery fish by removing the three left-lateral scutes anterior of an imaginary vertical line extended downward from the origin of the dorsal fin (Figure 2). Fish were then measured for fork length, weight, and assessed for the presence of fin deformities and overall health.

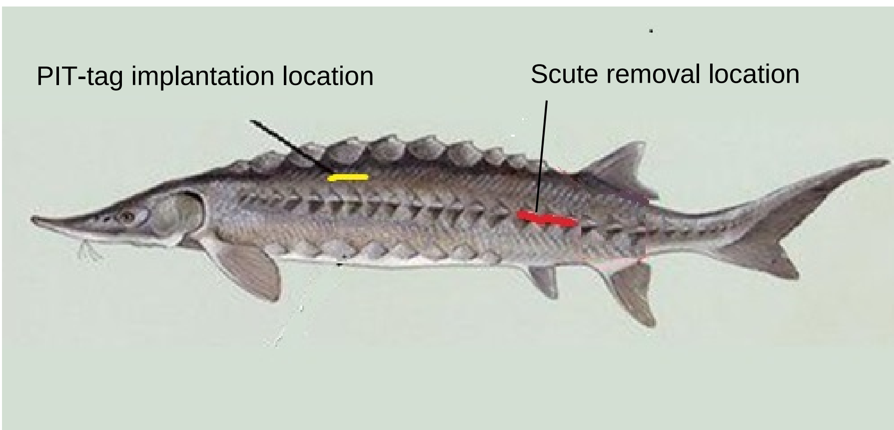

Figure 2 Juvenile White Sturgeon tag implantation and mark locations.

Tagging logistics and data collection were coordinated by BLE staff, with assistance from Grant PUD and YNSH staff during PIT-tagging and scute-marking activities. Data were recorded with a Biomark fish processing system and entered electronically into a Biomark P4 data processing program. Staff with BLE were responsible for implementing appropriate quality control/quality assurance protocols (e.g., fish handling and processing methods, daily data verification, and data backups) during fish processing and data recording. The data fields recorded were selected to document the genetic origin, holding and rearing water temperature, health and disposition, fin abnormalities, and the identifying tags and marks applied to each fish (Table 1).

Table 1 Data recorded in Biomark P4 for the 2019BYb White Sturgeon tagged and released in the Priest Rapids Project Area in 2021.

Data Field	Description
Session	Project Code – Year – Session ID
Project Code	GCS
Session Message	Record Release Pool (Wanapum or Priest Rapids) and Parental Family (1-5)
Rec #	Sequential record number
PIT-Tag Code	HEX format
SRR code	Three-character code that identifies the species (White Sturgeon), run, and rear type of fish (B0W)
Event Type	Mark
Length (mm)	Measured for all fish; tip of snout to tail fork (nearest 1 mm)
Weight (g)	Measured for all fish (nearest 1 g)
Event Site	Yakama Nation Sturgeon Hatchery (YNSH)
Text Comments	Recorded fin deformities and if the fish were in poor health
Event Date	Date and time when each fish was tagged
Event Site	YNSH
Life Stage	Juvenile
Brood Year	2019
Spawn Year	2019
Release Site	COLR7
RKm Mask	0
Organization	GPUD
Capture Method	None
Mark Method	Hand
Mark and Holding Temperature	In Celsius
Hatchery	MSDH (YNSH)

2019BYb Releases

In 2021, juvenile White Sturgeon were held in the hatchery for approximately two weeks post-tagging to allow recovery from the tagging process. The release of 2019BYb fish into the PRPA was coordinated by Grant PUD biologists and technicians, who worked with staff and equipment provided by YNSH and Grant PUD. In 2021, fish destined for Wanapum reservoir were released at the Vantage boat launch (RM420.6), while fish destined for Priest Rapids reservoir were released at the Priest Rapids Recreation Area boat launch (RM400.3).

Transport and release of the 2019BYb fish was conducted using a Grant PUD hatchery fish transport truck and a custom sturgeon transport trailer pulled with a Grant PUD pick-up truck. Both transport vehicles were equipped with onboard oxygen regulation systems to maintain oxygen levels during transport. During the transfer, staff monitored water temperature and dissolved oxygen levels as follows:

- during fish transfer from holding pens to the transport vehicle at YNSH;
- during transport at a minimum of two scheduled check stops; and,
- during release of the fish.

Transport manifest forms were completed by field staff to record the above information, as well as the date and time of water quality checks and the arrival, release, and departure times during the transfer. Total travel time from the YNSH to the Project area release sites was approximately 2 hours, with two water quality checks conducted approximately 40 minutes apart during transport. Fish were released from the transport vehicle to the river either by dip net or via a flexible flume. Buckets of water and nets were used to evacuate any remaining fish from the transport vehicle tanks. An effort was made to scare fish away from the wheels of the transport truck and trailer before they were driven out of the water. Any mortalities associated with the transport or release of fish were identified and the PIT tag number recorded for later removal from the release group record set. After release, the inside of the transport tank was inspected for shed PIT tags, and if found, the PIT tag numbers were recorded for later removal from the record set.

2.3 Broodstock Capture

Broodstock capture effort since 2015 have been conducted in John Day reservoir, immediately downstream of McNary Dam, and entailed a collective effort of public utilities, government agencies, and consultants in support of the White Sturgeon conservation aquaculture program at YNSH. In 2021, angling efforts were conducted by Grant PUD and BLE biologists below McNary Dam to capture adult White Sturgeon as broodstock. Captured White Sturgeon were surgically examined by a BLE biologist to determine sex and maturity. Mature fish identified as candidate broodstock were transported to the YNSH by BLE staff in the Grant PUD sturgeon transport trailer for further examination and gamete extraction.

2.4 Adult White Sturgeon Population Indexing

The 2021 adult White Sturgeon population assessment was a capture-recapture study conducted in a manner consisted with methodologies used in 2015 and 2018. The capture session was conducted from August 16 to 25; the recapture session was conducted approximately two weeks later from September 9 to 18 to allow fish time to recover and redistribute after initial capture. The late summer was selected for the assessment based on an assumption that the metabolic activity of White Sturgeon would be high at this time due to warm water temperatures and that fish would be broadly dispersed and actively feeding throughout each reservoir. The 2021 study was initiated in mid-August, slightly earlier than previous adult capture efforts, but overlapped previous efforts in terms of timing, flow levels, and water temperatures (Golder 2016, 2019).

Sampling was conducted by Golder Associates Ltd. (Golder) and BLE field crews using two research vessels to deploy gear and process fish. Set line deployment gear and methods were identical to those used during the 2018 adult indexing program (Golder 2019). Set lines were approximately 183 m long and consisted of a 0.64 cm diameter nylon mainline, anchored at both ends with a 25 kg piece of metal rail track attached to float retrieval lines. Up to 30 gangions baited with pickled squid were attached to the ground line at 4.6 m intervals. Gangions were refurbished in 2021 by Grant PUD staff, which entailed the exchange or sharpening of all hooks and standardizing gangion length to approximately 0.5 m in length. Each gangion consisted of a swivel-snap, a length of round or three-braid tarred ganging, and a single circle hook. Three sizes of barbed circle hooks [i.e., small hooks #7 (12/0), medium hooks #5 (14/0), and large hooks #3 (16/0)] were used to allow capture of a wide range of size classes. Ten gangions of each hook size (i.e., 30 gangions total) were placed in random order on each line. Set lines were set overnight and pulled approximately every 24 hours during sampling (i.e., referred to as a “overnight set”).

Set line sample locations were selected using a generalized random-tessellation stratified (GRTS) sample design based on the same sample multi-density reservoir categories (lower, middle, and upper sections) as used in the juvenile indexing study (see Section 1.0). In total, 192 GRTS sites were sampled over two sample sessions in 2021, with 96 sites sampled per session; 66 sites in Wanapum reservoir (i.e., 22 site per reservoir section) and 30 sites in Priest Rapids reservoir (i.e., 10 sites per reservoir section). Sample effort in 2021 was similar to the 2015 and 2018 studies and similar to that expended during the 2010 and 2012 studies (Golder 2011, 2013, 2016, and 2019). Separate sets of GRTS sites were generated for the capture and recapture sessions to eliminate sampling bias and ensure complete randomization of sample locations.

Fish were handled and processed in a manner similar to previous adult indexing capture programs (Golder 2019). All captured fish were scanned for a PIT tag and a PIT tag was applied if one was not detected. Fish that received a PIT tag were scanned to verify the PIT tag was functional and then marked by removal of the second left lateral scute. Once the PIT tag number was confirmed, weight and fork length were recorded. Sex and maturity of adult wild and 2002BY fish were assessed by surgical examination and visual inspection of the gonads with an otoscope. The assessment of sex and maturity followed the methods used in the upper Columbia River White Sturgeon Recovery Program (Table 2; UCWSRI 2006). All data were entered in the field, directly into Golder’s Adult White Sturgeon capture database. Hook size, identifying marks, and fish health and disposition were recorded for each fish captured. A canopy was deployed over the rear half of the boat to protect fish from direct sunlight and reduce overall thermal stress and exposure to UV radiation during processing.

Table 2 Sexual maturity codes for White Sturgeon (adapted from Bruch et al. 2001).

Sex	Code	Developmental State Description
Male	Mv	**Virgin male juvenile**; Testes are ribbon-like in appearance with lateral creases or folds , dark grey to cream colored attached to a strip of adipose fat tissue.
	M1	**Developing male**; Testes are tubular to lobed, light to dark grey, and embedded in substantial amounts of fat. Testes moderately to deeply lobed have distinct lateral folds.
	M2	**Fully developed male**; Testes large, cream to whitish in color, deeply lobed and filling most of the abdominal cavity. If captured during active spawning, may release sperm if stroked posteriorly along the abdomen.
	M3	**Spent/recovering male**; Testes size are much reduced, with very distinct lobes and whitish to cream color.
	M0	**Male based on previous capture**; general unknown maturity
Female	Fv	**Virgin female juvenile**; small feathery looking, beige ovarian tissue attached to a thin strip of adipose fat tissue.
	F1	**Early developing female**; pinkish/beige ovarian tissue with brain-like folds and smooth to rough surface, imbedded in heavy strip of fat tissue. The visible whitish eggs are <0.5 mm in diameter. Ovarian tissue of F1 females that have previously spawned is often ragged in appearance.
	F2	**Early "yellow egg" female**; Yellowish/beige ovarian tissue with deep "brain-like folds embedded in extensive fat tissue giving it a bright yellow appearance. Eggs, 1 to 2 mm in diameter with no apparent grayish pigmentation.
	F3	**Late "yellow egg" female**; large yellowish ovaries with deep lateral folds and reduced associated fat. Yellow/greenish to grey eggs 2.5 mm in diameter. May indicate next year spawning.
	F4	**"Black egg" female**; Large dark ovaries filling much of the abdominal cavity. Exhibiting a distinct "bulls-eye". Very little fat, Eggs are still tight in the ovary, dark grey to black, shiny and large, >3 mm in diameter.
	F5	**Spawning female**; Loose flocculent-like ovarian tissue with eggs free in body cavity shed in layers from deep ovarian folds. Eggs large, from grey to black, similar to F4.
	F6	**Post spawn female**; ovaries immediately after spawning are folded with a mushy pinkish and flaccid appearance, with little or no associated fat. Post spawn females display a characteristic abdominal mid-line depression. Large dark degeneration eggs buried amongst small oocytes.
	F0	**Female based on previous capture**; general unknown maturity
Unknown	97	adult based on size, (i.e., 1.5 m FL or greater) no surgical examination
	98	juvenile/sub-adult based on size, (i.e., no surgical examination)
	99	gonad undifferentiated or not visible during surgical examination

2.5 Adult Population Abundance Estimate

In 2015, the combined Wanapum and Priest Rapids adult mark-recapture data from the September-October adult indexing programs in 2010, 2012, and 2015 were used to construct a POPAN model to estimate adult population abundance (Golder 2016). Insufficient mark-recapture data for wild and 2002BY sturgeon were collected during the 2018 adult assessment to use the POPAN model approach. If insufficient data were collected in 2021, the

2015 model results would be used as a baseline, and new estimates for 2021 wild and 2002BY fish abundance would be calculated based on capture proportions.

Due to increased catch in 2021, the dataset was sufficient to run a set of Cormack-Jolly-Seber (CJS) models for data collected in the adult capture-recapture program. Data from broodstock collection were removed to ensure consistency of sampling between survey years, resulting in a dataset of adult White Sturgeon captured in 2010, 2012, 2014, 2018, and 2021. In a deviation from previous analyses, the data analyzed only included the 2010-2021 mark-recapture data, as opposed to also including the data on the time of original release of the hatchery-reared fish. This allowed the analysis of survival and abundance relative to the reservoir of sampling, as opposed to reservoir of release, since entrainment was very low in the combined 2010-2021 dataset (only one case of a fish entraining from Wanapum into Priest Rapids).

The POPAN model parameterization, which was used for the CJS models, contains four parameters – probability of survival, probability of recapture, probability of entering the population, and a super-population value. The super-population is a purely mathematical construct, and can be thought of as a pool of animals that may enter the population during the course of the study. The probability of entry is the probability of a new animal from the super-population entering the population (via birth, immigration, or recruitment to gear).

Multiple POPAN models were constructed to assess the effects of group (wild, 2002BY, and 2010BY-2019BY fish) and time on survival and recapture. Non-converged models were removed from analysis, and the remainder underwent a model selection process using quasi-likelihood-adjusted Akaike's Information Criterion corrected for small sample size (QAICc), where a lower value indicates better support for the model. The best model (i.e., the model with the lowest QAICc) was used to produce estimates of survival, recapture, and population abundance.

The following specifications of survival were used:

1) As constant for all fish and times, except for the 2015–2018 period, when 2002BY survival was allowed to differ, to reflect the cull / fishery.
2) As constant for all fish and times, except for the 2015–2018 period, when each group of fish (i.e., wild, 2002BY, and 2010BY–2019BY) survivals were allowed to differ, to reflect the potential of the fishery harvest to affect all three groups of fish.
3) As an additive function of group (i.e., wild, 2002BY, and 2010BY–2019BY) and whether the time period included the cull / fishery.
4) As a multiplicative function of group (i.e., wild, 2002BY, and 2010BY–2019 BY) and whether the time period included the cull / fishery.

The following specifications of recapture probabilities were used:

1) As a function of sampling occasion
2) As an additive function of sampling occasion and group (i.e., wild, 2002BY, and 2010BY–2019BY)

The probability of entry into the population was modeled as follows:

1) A trend over time for 2010BY–2019BY and forced to zero for both 2002BY and wild fish, as well as for the 2010BY–2019BY fish in 2010 and 2012, reflecting that these fish were not yet recruiting to the gear during these years.

The super-population was modeled as follows:

1) Constant
2) A function of group (i.e., wild, 2002BY, and 2010BY–2019BYa)

All data analyses were performed in R v. 4.0.4 (R Core Team 2021) and MARK (White and Burnham 1999) through the package 'RMark' (Laake 2013). Following model selection, the estimated survival, recapture, and entry probabilities were exported. In addition, estimated population size on each sampling occasion was calculated, both by group and as an overall wild and hatchery-reared population within the Wanapum and Priest Rapids reservoirs. These estimates were then split by reservoir using the annual proportion of fish captured within each reservoir.

2.6 Juvenile White Sturgeon Population Indexing

The methods used during the 2021 juvenile White Sturgeon population indexing program were consistent with standardized methodologies applied during indexing studies conducted since 2016 (Golder 2015–2021). Juvenile White Sturgeon mark-recapture efforts were conducted with small-hook (2/0 and 4/0) set line sampling gear deployed in Wanapum and Priest Rapids reservoirs. Each set line was 122 m long and was deployed with 40 gangions spaced 3 m apart. Each gangion consisted of a swivel snap, a length of 150# monofilament leader, and either a 2/0 or 4/0 circle hook baited with pickled squid. Sampling was conducted in Wanapum reservoir by Golder and BLE using separate research vessels to deploy gear and process fish. Set lines were left to sample overnight (i.e., defined as "overnight set" or approximately 24-hours) and were retrieved and reset the following day.

Consistent with previous study years, set line locations in 2021 were selected using a single pass, unstratified, unequal probability GRTS sampling design (Stevens and Olsen 2004). The GRTS sample locations were determined with the spsurvey package (Kincaid 2007) developed for the R statistical program (R version 4.0.5; R Core Team 2021). The 2021 survey used the same sample multi-density reservoir categories (lower, middle, and upper sections) used in previous study years (Golder 2021). The Wanapum reservoir GRTS sample sites were constrained to sections of the reservoir where water depth was typically 15 m or greater, based on available bathymetric data. In Priest Rapids reservoir, site selection was constrained to the area encompassed within the ≥6 m bathymetric contour, consistent with previous GRTS sampling effort within Priest Rapids reservoir. The sample depth criteria for each reservoir were selected to exclude shallow water areas within the lower, middle, and upper reservoir sections that exhibit dense aquatic macrophyte growth.

In Wanapum reservoir, the spsurvey package specified a GRTS sample draw of 270 sites (with a 50% overdraw) with sites allocated equally among the three reservoir sections (i.e., 90 sites per section). In Priest Rapids reservoir, the specified GRTS draw was 90 sites (with 50% overdraw) with sites allocated equally among reservoir sections (i.e., 30 sites per section). In both reservoirs, sampling intensity increased from downstream to upstream sections because the areal extent of each section progressively decreased moving upstream. In 2021, set line deployment and retrieval, catch processing, and data recording were conducted in a manner consistent with previous indexing studies (Golder 2021).

The relationship between White Sturgeon fork length (log10 transformed FL) and weight data was estimated via linear regression for each reservoir separately. Condition was estimated by calculating relative weight based on the standard weight (Ws) equation for White Sturgeon: $Ws = 2.735\ E\text{-}6 * FL^{3.232}$ (Beamesderfer 1993). Absolute growth (cm) in FL and average annual growth rate (cm/year) in FL between tagging and capture was calculated for individual fish. For White Sturgeon caught more than once during the survey, data from the first capture was used in growth calculations. In addition to calculations of catch-per-unit-effort (CPUE) based on hook-hours (i.e., 1 hook set for 1 hour), the proportion of efforts where catch was greater than zero (Ep; Counihan et al. 1999; Bannerot and Austin 1983; Uphoff 1993), referred to as the proportion of positive catch, was also calculated for comparisons of catch rate between the two reservoirs and reservoir sections within each reservoir.

2.7 Juvenile White Sturgeon Growth, Survival and Abundance Estimation

Age and length data from recaptured hatchery-released fish were used to construct von Bertalanffy growth curves (length-at-age curves). The curves were used to assess whether growth slowed as sturgeon density in the reservoirs increased. All analyses were performed using the package FSA (Ogle et al. 2020) in the statistical environment R v. 4.0.4 (R Core Team 2021).

A separate von Bertalanffy model was constructed for each brood year (up to 2018BY) in each of the two reservoirs. The curves were overlaid to visually assess differences in growth between the different brood years in the two reservoirs.

Mark-recapture data from sampling conducted during the juvenile White Sturgeon sampling programs since 2014 were used to construct a Cormack-Jolly-Seber model that was used to estimate survival of hatchery juveniles in Wanapum and Priest Rapids reservoirs. The analysis was conducted using the statistical environment R v. 4.0.4 (R Core Team 2021), interfaced with Program MARK (White and Burnham 1999) through the package 'RMark' (Laake 2013). Recapture data for fish that moved to a different reservoir were removed from the dataset – that is, any recaptures that took place after the immigration, were removed from the analysis. A total of 193 fish moved between reservoirs, of which 192 moved from Wanapum reservoir into Priest Rapids reservoir, and one fish moved in the opposite direction. Since the two reservoirs were analyzed together, it means that fish that were entrained from Wanapum were correctly modeled as being lost from the population in Wanapum reservoir, but they are not added to the population in Priest Rapids reservoir. Since only a small proportion of all recaptured fish were shown to have migrated (193 fish out of a total of 7,270 fish that were recaptured at least once; 2.7%), a large bias in the population estimates of Priest Rapids reservoir is unlikely.

Only hatchery fish released in the PRPA between 2011 and 2020 were included in the analysis. Wild fish and fish that were released elsewhere and entrained into the PRPA (i.e., fish originating from Rocky Reach reservoir) were removed from the analysis. The models assumed that all fish were released at age-1.

Brood year was included as a predictor in the estimates of survival. The 2018BY and 2019BYa brood years were combined into a single, 2018-2019 brood year, to enable convergence. In addition, the 2010BY was allowed to have two separate estimates of survival – one during the 2015/2016 cull / fishery period, and another outside of this period. Models were constructed using all combinations of the following survival and recapture specifications:

a) Survival:
    a. as an additive function of brood year and first year post-release and all subsequent years – i.e., survival differs between brood years, and the survival for first year post-recapture survival is allowed to be different than survival in all subsequent years.
    b. as a multiplicative function of release reservoir and whether the period was in the first year post release or in all subsequent years – i.e., survival for first year post-release and all subsequent years was allowed to differ independently by reservoir.
    c. as a multiplicative function of release reservoir and brood year, with an additive effect of whether the period was in the first year post release or in all subsequent years – i.e., survival for first year post-release and all subsequent years was allowed to differ independently by reservoir.
b) Recapture:
    a. as a multiplicative function of reservoir and age (as a categorical variable) – i.e., recapture by age is allowed to vary independently by release reservoir.
    b. as a multiplicative function of release reservoir and age (as a categorical variable), with an additive effect of brood year
    c. as a multiplicative function of release reservoir and age (as a continuous variable with a parabolic effect) – i.e., the parabolic trend by age is allowed to differ between release reservoirs.

The candidate models were evaluated using quasi-likelihood-adjusted Akaike's Information Criterion corrected for small sample size (QAICc), where a lower value indicates better support for the model. The full model set was then model-averaged to provide estimates of survival and recapture values. The survival estimates were used to calculate cumulative mean annual population values, with 95% confidence intervals, to describe the abundance of hatchery juvenile White Sturgeon released in the PRPA for each calendar year from 2011 to 2020. Estimation of survival and recapture was only possible for brood year releases with one or more years at large and could not be estimated for the 2019BYb released in 2021. To account for the 2019BYb abundance, the number of 2019BYb fish released in 2021 was used as the abundance of that brood year.

2.8 General Data Recording and Analysis

Custom field databases were designed and used to record field data for each study component. In 2021, copies of the adult and juvenile White Sturgeon indexing databases, with custom data fields specific to the study data requirements, were used by field crews to record indexing data in both Wanapum and Priest Rapids reservoirs. When White Sturgeon were captured during PRPA White Sturgeon population indexing assessments, White Sturgeon were identified based on scute markings and were assigned either as "H-123LAD" if a YNSH origin fish (2010BY-2019BY), as 'H-CRITFC" if a CRITFC origin fish (2002BY), or as wild fish "W" if identified scute marks were not found or if previously scute marked as a wild fish (remove of second left or second right scute). Final field databases were proofed for errors and then merged into a final database for each study component. Within and between the various relational databases developed for the M&E studies, queries were used to extract data, screen for errors, and analyze annual and inter-year data to determine movement, growth, and capture histories of hatchery juvenile White Sturgeon. Additional post-collection error screening and data proofing was conducted using the statistical environment R, v. 4.0.5 (R Core Team 2021). Summary tables and rudimentary data checks were conducted in Excel®. All figures were created in R using the package ggplot2 (Wickham 2009). Customized datasheets and manifests were used to record information during the juvenile release.

3.0 Results

3.1 Discharge and Temperature During Study Components

In 2021, peak mean daily flows in the PRPA, as measured in Wanapum reservoir below Rock Island Dam, were recorded on June 7 (5,445 m^3/s; DART 2021). Lowest mean daily discharge was recorded on October 9 (901 m^3/s). Peak mean daily water temperature was recorded on August 18 (20.3°C). The lowest mean daily water temperature was recorded on February 14 (2.7°C; Figure 3). The peak discharge volume and total discharge volume in the PRPA was 19,675 kilo-acre feet (KAF) and 78,770 KAF, respectively (NOAA 2021).

2019BYb Hatchery Juvenile White Sturgeon Release

Hatchery juveniles are typically released into the PRPA in late spring, approximately two weeks after tagging, to allow the fish to recuperate from tagging and to time the release with the rising hydrograph and when the receiving water temperatures range from 8°C to 12°C. Due to implementation of a COVID-19 mitigation plan, the release of the 2019BYb was conducted according to schedule and proceeded on April 20 during the ascending limb of the hydrograph. At release, the mean daily discharge was 2,951 m^3/s and the mean daily water temperature was 7.5°C.

Adult White Sturgeon Population Indexing

The 2021 adult White Sturgeon indexing capture session was conducted from August 16 to 25 during the descending limb of the summer hydrograph and when water temperatures were at or near the seasonal high (Figure 3). During sampling, average mean daily discharge was 2,858 m^3/s (SD = ±338 m^3/s) and ranged from a low of 2,266 m^3/s on August 17 to a high of 3,326 m^3/s on August 19. Mean water temperature during sampling was 20.0°C (SD = ±0.3°C) and ranged between 19.5°C and 20.3°C.

The 2021 adult White Sturgeon indexing recapture session was conducted from September 9 to 18 when flows approached seasonal lows and water temperatures were near the seasonal high (Figure 3). During sampling, average mean daily discharge was 1,572 m^3/s (SD = ±226 m^3/s) and ranged from a low of 1,314 m^3/s on September 18 to a high of 2,038 m^3/s on September 16. Mean water temperature during sampling was 19.4°C (SD = ±0.4°C) and ranged between 18.8°C and 19.8°C. During both sessions of adult indexing, load-following by upstream and downstream hydroelectric facilities resulted in large daily variations in discharge and reservoir level.

Juvenile White Sturgeon Population Indexing

Juvenile White Sturgeon indexing in 2021 was conducted from September 27 to October 23 when flows approached seasonal lows and water temperatures gradually decreased from seasonal highs over the course of sampling (Figure 3). During sampling, average mean daily discharge was 1,743 m^3/s (SD = ±395 m^3/s) with substantial fluctuations from a low of 902 m^3/s on October 9 to a high of 2,645 m^3/s on October 8. During juvenile indexing, load-following by upstream and downstream hydroelectric facilities resulted in large variations in hourly and daily discharge. Mean water temperature during sampling was 16.5°C (SD = ±0.8°C) and ranged between 15.5°C and 17.9°C.

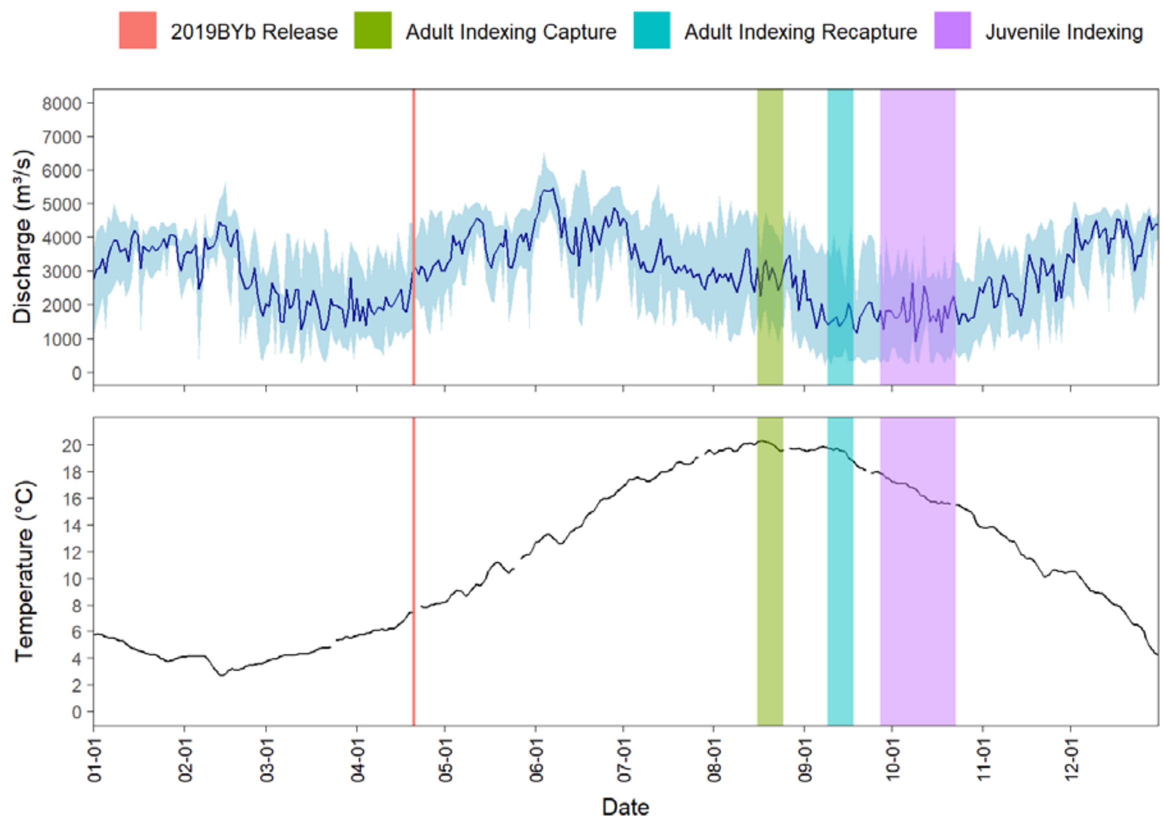

Figure 3 **Mean daily discharge (dark blue line), mean hourly discharge (light blue ribbon), and mean hourly water temperature (black line) of the Columbia River in the Priest Rapids Project Area, as measured below Rock Island Dam in 2021 and the timing of the 2019BYb juvenile White Sturgeon release (red column), adult White Sturgeon indexing capture and recapture sessions (green and blue columns, respectively), and juvenile White Sturgeon indexing (purple column).**

3.2 2019BYb Hatchery Juvenile White Sturgeon Marking and Release

All 2019BYb were tested for spontaneous autopolyploidy, processed, and tagged from April 6 to 8, 2021. The 2021 Grant PUD juvenile White Sturgeon release was limited to individuals that tested negative for spontaneous autopolyploidy. In total, 16 autopolyploidy fish were identified out of the 1501 fish tested. These autopolyploidy fish were found in only three of the four maternal families even though preliminary testing in 2020 indicated the presence of spontaneous autopolyploidy in all four families (Chris Mott, Grant PUD, personal communication, November 16, 2021).

All fish were released on April 20, approximately 12 days after tagging. A total of 1,485 fish were released in the Project area, which was approximately 46% of the historical annual hatchery juvenile White Sturgeon release (i.e., a maximum of 3,250 fish) prescribed under the Priest

Rapids White Sturgeon Stocking SOA. In accordance with the SOA, 936 fish (62%) were released in Wanapum reservoir at the Vantage boat launch (RM420.6) and 549 fish (38%) were released in Priest Rapids reservoir at the Priest Rapids Recreation Area boat launch (RM400.3; Table 3). Mean fork length of the 2019BYb when tagged was 483 mm (SD = ± 52 mm) and mean weight was 783 g (SD = ± 265 g).

During transport of the fish, oxygen levels were maintained between 7 and 12 mg/L and the increase in the transport tank water temperature was less than 1°C. At release, the difference in temperature between the transport water and receiving water was less than 3°C. Shed PIT tags were not found in the rearing tanks or in the holding tanks of the transport vehicles. Mortalities were not recorded during transport. All fish were successfully released alive and post-release mortalities were not observed by the crew.

Table 3 Number of 2019BYb juvenile White Sturgeon released in Wanapum and Priest Rapids reservoirs and the mean fork length (FL) and mean weight of fish in each release. April 20, 2021.

	2021 White Sturgeon 2019BYb Release		
Release Location Reservoir (River Mile)	**No. of Fish**	**Mean FL (± SD) mm**	**Mean Weight (± SD) g**
Wanapum (420.6)[1]	936	483 (±51)	776 (±257)
Priest Rapids (400.3)[2]	549	482 (±53)	795 (±277)
Total	1,485	483 (±52)	783 (±265)

[1] Vantage boat launch

[2] Priest Rapids Recreation boat launch

During tagging, taggers noted that essentially all the 2019BYb had one or more fin deformities and that most of the fish had deformities in all fins. Due to high prevalence of fin deformities, the tagging personnel made note of which fins were not deformed as opposed to listing the fin deformities for each fish. In general, the dorsal fin was the least deformed fin of the fish tagged.

3.3 2021 Broodstock Capture and 2021BY Production

During the 2021 broodstock capture efforts, a total of 91 sturgeon were landed, with 87 individual White Sturgeon captured and 4 fish captured twice. Of these, 56 individual White Sturgeon of mature spawning size (i.e., greater than 150 cm fork length) were captured. In total, 6 ripe females and 6 ripe males were transported to YNSH for further examination and gamete extraction. On June 10, a 6x6 spawning matrix was conducted and sufficient gametes were obtained to produced 32 genetic families (6 families from 5 females; 2 families from 1 female).

3.4 Adult White Sturgeon Population Assessment

In Wanapum and Priest Rapids reservoirs, areal-based GRTS unequal probability site selection assigned equal numbers of sites among the three defined sections (i.e., lower, middle, and upper sections) in each reservoir (Table 4). Sample intensity (samples/100 ha) in the upper reservoir sections of each reservoir was from 6 to 7 times higher compared to the lower reservoir sections due to the decline in the areal extent of the available sample area from downstream to upstream.

The mean depth and the range of depths sampled was greater in Wanapum reservoir (mean = 20.5 m; range = 11.5 to 46.0 m) than in Priest Rapids reservoir (mean = 10.4 m; range = 4.5 to 20.5 m). Mean water depths at sample sites in the upper sections of both Wanapum and Priest Rapids reservoirs were slightly less compared to mean depths recorded in the lower and middle sections of both reservoirs. At some sample sites, minimum water depths less than the bathymetric minimum depth criteria for each reservoir (i.e., 15 m in Wanapum reservoir and 6 m in Priest Rapids reservoir) were recorded due to variation in bathymetry over the length of the set line. All adult indexing set lines were successfully retrieved after maximum deployment times that ranged from 15.2 to 43.4 hours. Deployment periods greater than 38 hours or more were due to inclement weather and water conditions that prevented retrieval of some set lines until the following day.

Table 4 Details of GRTS sample site distribution among Priest Rapids and Wanapum reservoir sections, areal extent of reservoir sections, estimates of sampling intensity, sample depth, and duration of overnight set lines deployed during the adult White Sturgeon indexing program, August 16 to September 18, 2021.

	Reservoir							
	Priest Rapids (6 m Bathymetric Contour)				Wanapum (15 m Bathymetric Contour)			
	Lower	Middle	Upper	All	Lower	Middle	Upper	All
Number of GRTS sites sampled per section	20	20	20	60	44	44	44	132
Sampling area (ha)	1,369	346	213	1,928	1,664	727	308	2,699
Samples/100 ha	1.5	5.8	9.4	3.1	2.6	6.1	14.3	4.9
Sample depths (m)								
mean	12.4	9.3	9.6	10.4	23.0	19.8	18.8	20.5
min	4.5	4.5	6.0	5.0	14.0	13.2	11.5	12.9
max	20.5	14.5	13.8	16.3	46.0	28.0	27.0	33.7
Sample duration (h)								
mean	21.2	20.9	21.0	21.0	24.0	20.3	19.1	21.1
min	20.0	19.7	19.5	19.7	18.7	18.0	15.2	17.3
max	22.6	23.3	22.9	22.9	43.4	23.0	22.0	29.5

The average mean daily flow during the capture session (2,858 m^3/s; see Figure 3) was notably higher than during the recapture session (1,572 m^3/s), which permitted sampling of some deep water sites with high water velocity during the recapture session that could not be sampled during the capture session. The average mean daily water temperature during the capture session (20.0°C) and recapture session (19.4°C) were at or near the seasonal maximum, but the high water temperature did not delay recovery of sturgeon after capture and processing.

3.4.1 2021 Adult White Sturgeon Indexing Catch

In total, 443 White Sturgeon were captured and processed during the adult indexing program in Priest Rapids (n = 110) and Wanapum (n = 333) reservoirs (Figure 4; Table 5). These captures represented 436 individual fish, with seven fish captured twice in Wanapum reservoir between the capture and recapture sessions. Within-session recaptures were not recorded. In the combined catch from the capture and recapture sessions for both reservoirs, the 2013BY (123 of 443 fish; 28%) and the 2014BY (88 of 443 fish; 20%) contributed the largest proportion to the total catch. Lesser numbers of 2012BY (54 of 443 fish; 12%), 2017BY (45 of 443; 10%), and 2015BY (42 of 443 fish; 9%) were captured in similar proportions, with the remaining brood years (i.e., 2002BY, 2010BY, 2016BY, 2018BY, 2019BYa, 2019BYb), unknown hatchery fish, and wild fish contributing the remainder of the total catch. The 2002BY (20 of 443 fish; 5%) and wild fish (8 of 443 fish; 2%), represented the target 'adult' population of the indexing sampling effort and were only captured in low numbers.

Entrainment of recently released hatchery fish (i.e., 2010BY and younger) was evident in the catch data and included fish that were, 1) originally released in reservoirs upstream of the PRPA and then subsequently captured in the PRPA, and 2) fish that were originally released in Wanapum reservoir and subsequently captured in Priest Rapids reservoir (Table 5). Low numbers of fish from 2010BY to 2016BY that were originally released in Rocky Reach reservoir (n = 5 fish) or Wells reservoir (n = 1 fish) were captured in Wanapum reservoir. Hatchery fish originally released in Wanapum reservoir and captured in Priest Rapids reservoir contributed a substantial proportion to the total catch (34 of 109 fish; 31%) and were the majority of the 2013BY captured in Priest Rapids reservoir (19 of 31 fish; 61%).

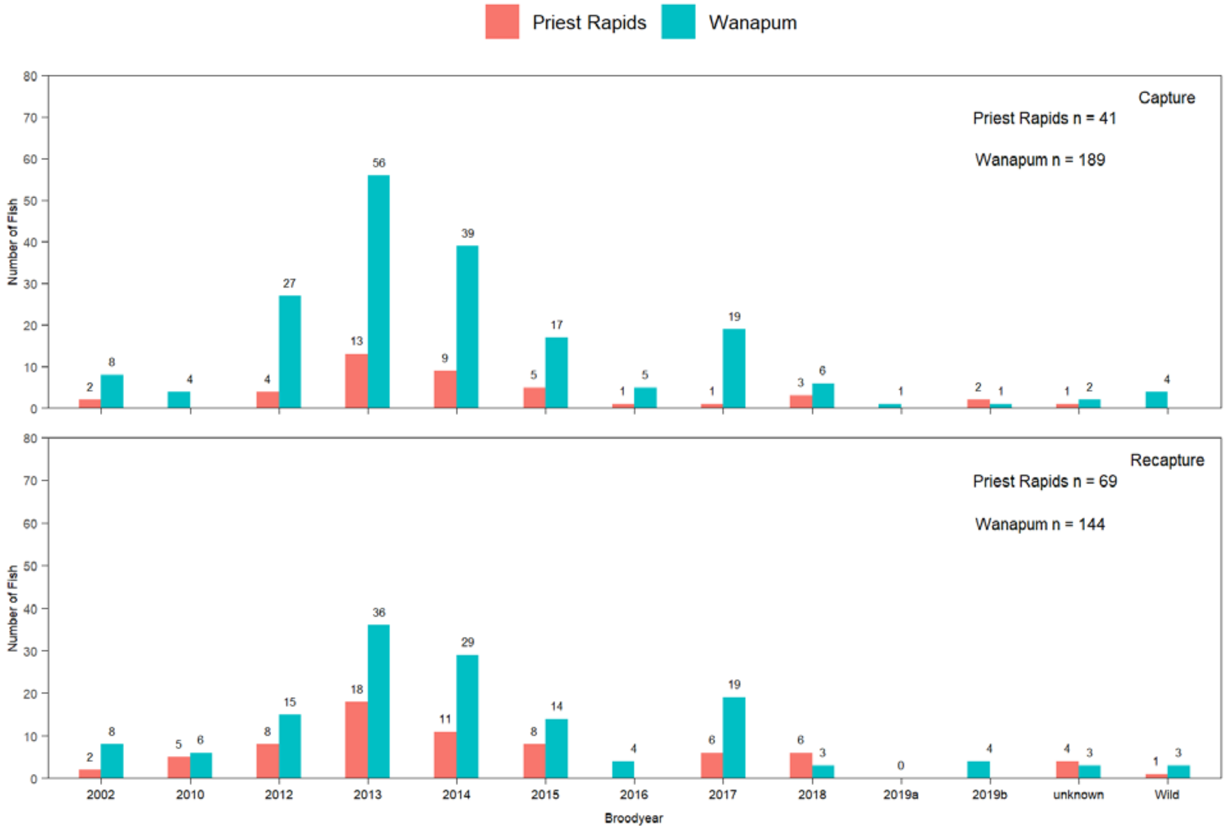

Figure 4 **Hatchery and wild White Sturgeon captured in the Priest Rapids Project area during capture (top pane) and recapture (bottom pane) sessions of the adult White Sturgeon indexing program, August 16 to September 18, 2021. The Unknown category represents fish suspected to be of hatchery origin but without a PIT tag to allow identified of origin and brood year.**

Table 5 **Hatchery and wild White Sturgeon captured in the Priest Rapids Project area during the White Sturgeon indexing program, August 16 to September 18, 2021.**

		Priest Rapids			Wanapum			
Brood Year	Release Reservoir	Capture	Recapture	Total	Capture	Recapture	Total	Grand Total
Upstream Releases								
2002	Rocky Reach	2	2	4	8	8	16	20
2010	Rocky Reach	-	-	0	1	-	1	1
2012	Rocky Reach	-	-	0	-	1	1	1
2013	Rocky Reach	-	-	0	-	1	1	1
2014	Rocky Reach	-	-	0	-	1	1	1
2015	Wells	-	-	0	1	-	1	1
2016	Rocky Reach	-	-	0	1	-	1	1
PRPA releases								
2010	Priest Rapids	-	3	3	-	-	0	3
	Wanapum	-	2	2	3	6	9	11
2012	Priest Rapids	4	8	12	-	-	0	12
	Wanapum	-	-	0	27	14	41	41
2013	Priest Rapids	5	7	12	-	-	0	12
	Wanapum	8	11	19	56	35	91	110
2014	Priest Rapids	7	6	13	-	-	0	13
	Wanapum	2	5	7	39	28	67	74
2015	Priest Rapids	5	4	9	-	-	0	9
	Wanapum	-	4	4	16	14	30	34
2016	Priest Rapids	1	-	1	-	-	0	1
	Wanapum	-	-	0	4	4	8	8
2017	Priest Rapids	1	6	7	-	-	0	7
	Wanapum	-	-	0	19	19	38	38
2018	Priest Rapids	3	5	8	-	-	0	8
	Wanapum	-	1	1	6	3	9	10
2019a	Wanapum	-	-	0	1	-	1	1
2019b	Priest Rapids	1	-	1	-	-	0	1
	Wanapum	1	-	1	1	4	5	6
Unknown[1]	-	1	4	5	2	3	5	10
Wild	-	-	1	1	4	3	7	8
Total		41	68	109	185	141	326	435

[1]Considered to be of hatchery origin based either on the presence of a PIT tag, marks, or substantial fin deformity, but brood year, source, or stocking location data are unknown.

3.4.2 Adult Indexing Catch Rates and Distribution

In total, 118,143 hook-hours of set line sample effort was expended during the 2021 adult White Sturgeon indexing program with similar levels of hook-hour effort between the capture session (60,778 hook-hours) and recapture session (57,365 hook-hours; Table 6). Sample effort was higher in the lower section of Wanapum reservoir due to high wind and wave conditions that delayed retrieval of five set lines until the following day. The effect on catch of the extended deployments is uncertain; however, the combined effort of these set lines resulted in the capture of only 5 fish of the 47 fish captured in Wanapum reservoir on August 23 when the set lines were retrieved.

During the capture session, the CPUE in Wanapum reservoir (0.45 fish/100 hook-hours) was higher than in Priest Rapids reservoir (0.22 fish/100 hook-hours); whereas, during the recapture session, the CPUEs in each reservoir were similar (0.37 fish/100 hook-hours in both reservoirs). A partial explanation for the difference during the capture session was that CPUEs in the middle sections of each reservoir differed substantially, with a much higher CPUE recorded in Wanapum reservoir (0.61 fish/100 hook-hours) than in Priest Rapids reservoir (0.13 fish/100 hook-hours). This discrepancy between capture and recapture session CPUEs was reflected in the overall CPUE for each reservoir, with a higher overall CPUE recorded in Wanapum reservoir (0.41 fish/100 hook-hours) than in Priest Rapids reservoir (0.29 fish/100 hook-hours).

Similar changes in CPUE based on Ep (the proportion of set lines that captured one or more fish) were evident, with higher Eps during the capture session in Wanapum reservoir than in Priest Rapids reservoir in the lower (Wanapum Ep = 0.82; Priest Rapid Ep = 0.60), middle (Wanapum Ep = 1.00; Priest Rapid Ep = 0.40), and upper section (Wanapum Ep = 0.77; Priest Rapid Ep = 0.50) in each reservoir (Figure 5). During the recapture session, Eps in the lower (Wanapum Ep = 0.68; Priest Rapid Ep = 0.60), middle (Wanapum Ep = .64; Priest Rapid Ep = 0.40), and upper (Wanapum Ep = 0.91; Priest Rapid Ep = 0.80) sections of each reservoir were more similar.

Table 6 Total set line sample effort, catch, and CPUE in the Priest Rapids Project area during the adult White Sturgeon indexing program, August 16 to September 18, 2021.

Session[1]	Reservoir	Reservoir Section	Sample Effort (hook-hours)	Catch (Number of fish)				CPUE (Fish/100 hook-hours)			
				Wild	H-123LAD	2002BY	Total	Wild	H-123LAD	2002BY	Wild & Hatchery
Capture	Wanapum	Lower	17,083	1	48	3	52	0.01	0.28	0.02	0.30
		Middle	12,778	2	71	5	78	0.02	0.56	0.04	0.61
		Upper	12,266	1	58	0	59	0.01	0.47	0.00	0.48
		all	42,127	4	177	8	189	0.01	0.42	0.02	0.45
	Priest Rapids	Lower	6,436	0	16	2	18	0.00	0.25	0.03	0.28
		Middle	6,264	0	8	0	8	0.00	0.13	0.00	0.13
		Upper	5,951	0	15	0	15	0.00	0.25	0.00	0.25
		all	18,651	0	39	2	41	0.00	0.21	0.01	0.22
Recapture	Wanapum	Lower	14,271	1	26	2	29	0.01	0.18	0.01	0.20
		Middle	12,521	0	49	1	50	0.00	0.39	0.01	0.40
		Upper	11,696	2	58	5	65	0.02	0.50	0.04	0.56
		all	38,488	3	133	8	144	0.01	0.35	0.02	0.37
	Priest Rapids	Lower	6,297	0	26	2	28	0.00	0.41	0.03	0.44
		Middle	6,252	0	13	0	13	0.00	0.21	0.00	0.21
		Upper	6,328	1	27	0	28	0.02	0.43	0.00	0.44
		all	18,877	1	66	2	69	0.01	0.35	0.01	0.37
All	Wanapum		80,615	7	310	16	333	0.01	0.38	0.02	0.41
	Priest Rapids		37,528	1	105	4	110	0.00	0.28	0.01	0.29
	PRPA	Total	118,143	8	415	20	443	0.01	0.35	0.02	0.37

[1] Capture Session, August 16 to 25, 2021; Recapture Session, September 9 to 18, 2021;

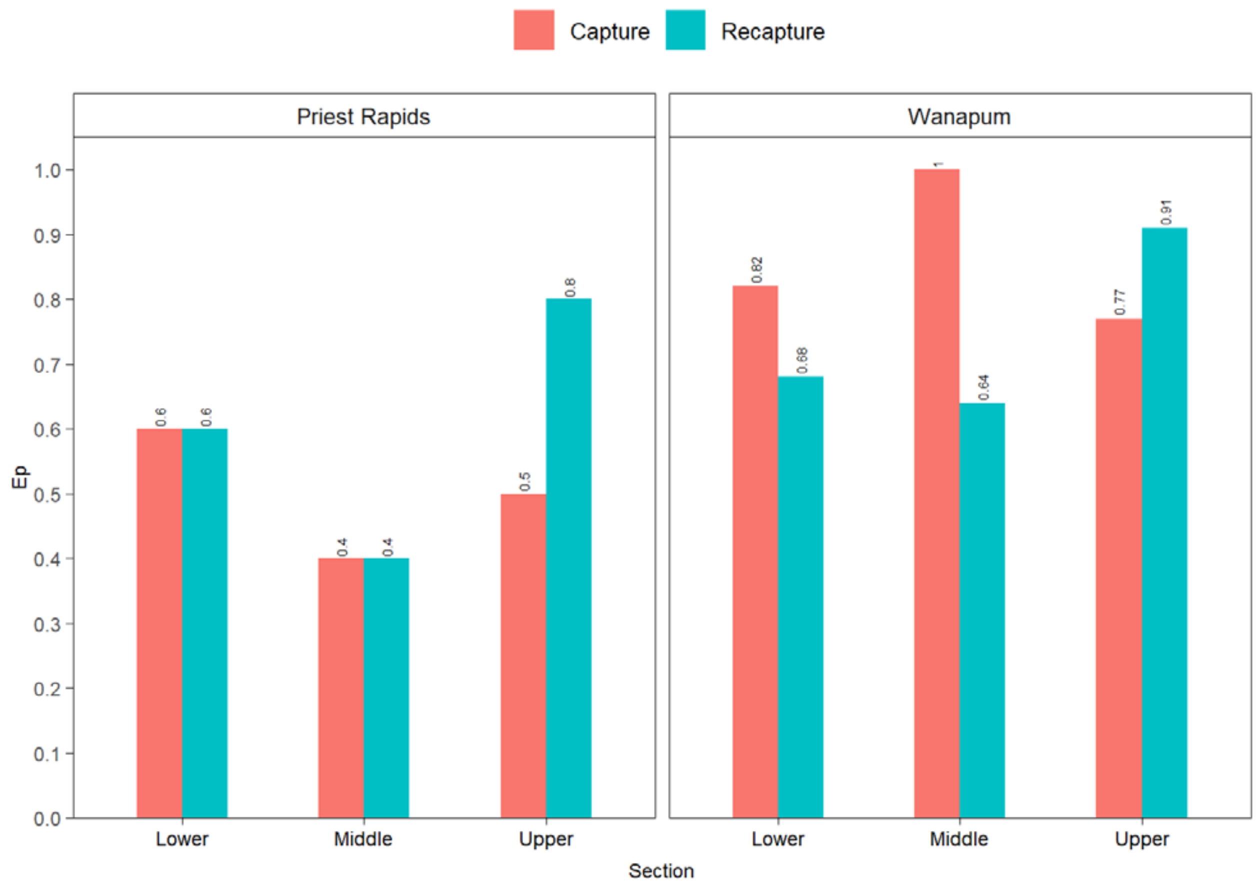

Figure 5 **Proportion of positive catches (Ep) recorded in the Priest Rapids Project area within the lower, middle, and upper section of each reservoir during the adult White Sturgeon indexing program, August 16 to September 18, 2021.**

During the capture session, 9 of 66 (13.6%) set lines deployed in Wanapum reservoir and 15 of 30 (50.0%) set lines deployed in Priest Rapids reservoir did not catch fish. During the recapture session, 17 of 66 (25.8%) set lines deployed in Wanapum reservoir and 12 of 30 (40.0%) set lines deployed in Priest Rapids reservoir did not catch fish (Figure 6). For the catch and recapture sessions combined, a higher proportion of zero-catch efforts were recorded in the lower section of Wanapum reservoir (11 of 44 sites; 25.0%) and in the middle section of Priest Rapids reservoir (12 of 20 sites; 60.0%). A small number of set lines caught a disproportionately high number of fish compared to the overall median catch of one fish per set line in Priest Rapids reservoir and two fish per set line in Wanapum reservoir. In Wanapum reservoir, 5% of set lines deployed (7 of 132 set lines) captured between 9 and 15 fish, which contributed 24% to the total catch (78 of 326 fish). Similarly, in Priest Rapids reservoir, approximately 5% of the set lines deployed (3 of 60 set lines) captured between 8 and 12 fish, which equated to 28% of the total catch (31 of 109 fish).

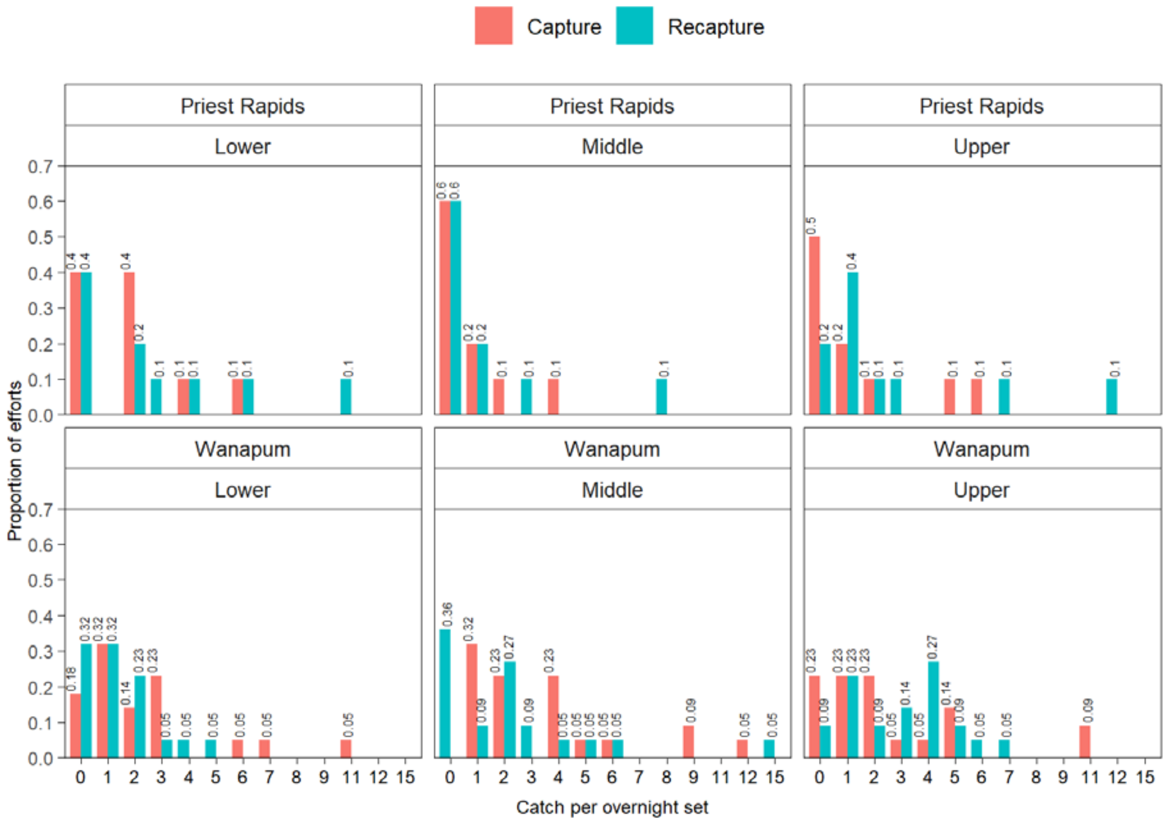

Figure 6 **Frequency of White Sturgeon catch-per-overnight-set during the adult White Sturgeon indexing program capture (August 16 to 25) and recapture (September 9 to 18) session in 2021.**

Catch, Effort and CPUE by River Mile

The GRTS unstratified unequal probability sample design distributed effort over the geographical area within each reservoir that encompassed the targeted minimum depth sample criteria (i.e., 15 m in Wanapum reservoir and 6 m in Priest Rapids reservoir). Histogram plots of catch, effort, and CPUE by River Mile indicated general areas within each reservoir where higher captures of White Sturgeon were encountered (Figure 7). The highest sample effort per River Mile was typically in the lower section of each reservoir, but especially the lower section of Wanapum reservoir where the river is very wide. Over the length of each reservoir, sample effort was reduced for a given River Mile if habitat within that River Mile did not meet the minimum depth criteria.

Overall, the lower and upper sections of Priest Rapids reservoir had slightly higher CPUEs by River Mile than in the middle section during both the capture and recapture sessions. In the lower section, higher CPUEs were recorded in the middle and upper portions of the section from RM401 to RM402, and near the boundary with the middle section at RM404, than in the lower portion closer to Priest Rapids Dam. In the middle section, CPUE were generally low throughout the section; however, higher CPUE was recorded at RM408 and suggests this could be a localized area where fish aggregate. The highest CPUEs in Priest Rapids reservoir were recorded in the upper section near the tailrace of Wanapum Dam at RM415.

In Wanapum reservoir, higher CPUEs by River Mile were recorded in the middle and upper sections compared to the lower section. In the lower section, CPUEs were low from RM416 to RM423, but increased substantially near RM425, a known overwintering and holding site for White Sturgeon. In the middle section, CPUEs were also generally low from RM426 to RM433, but increased substantially from RM434 to RM440. In the upper section, higher CPUEs were recorded from RM441 to RM442, but decreased after RM443. Higher CPUEs were recorded in the upper section near RM451.

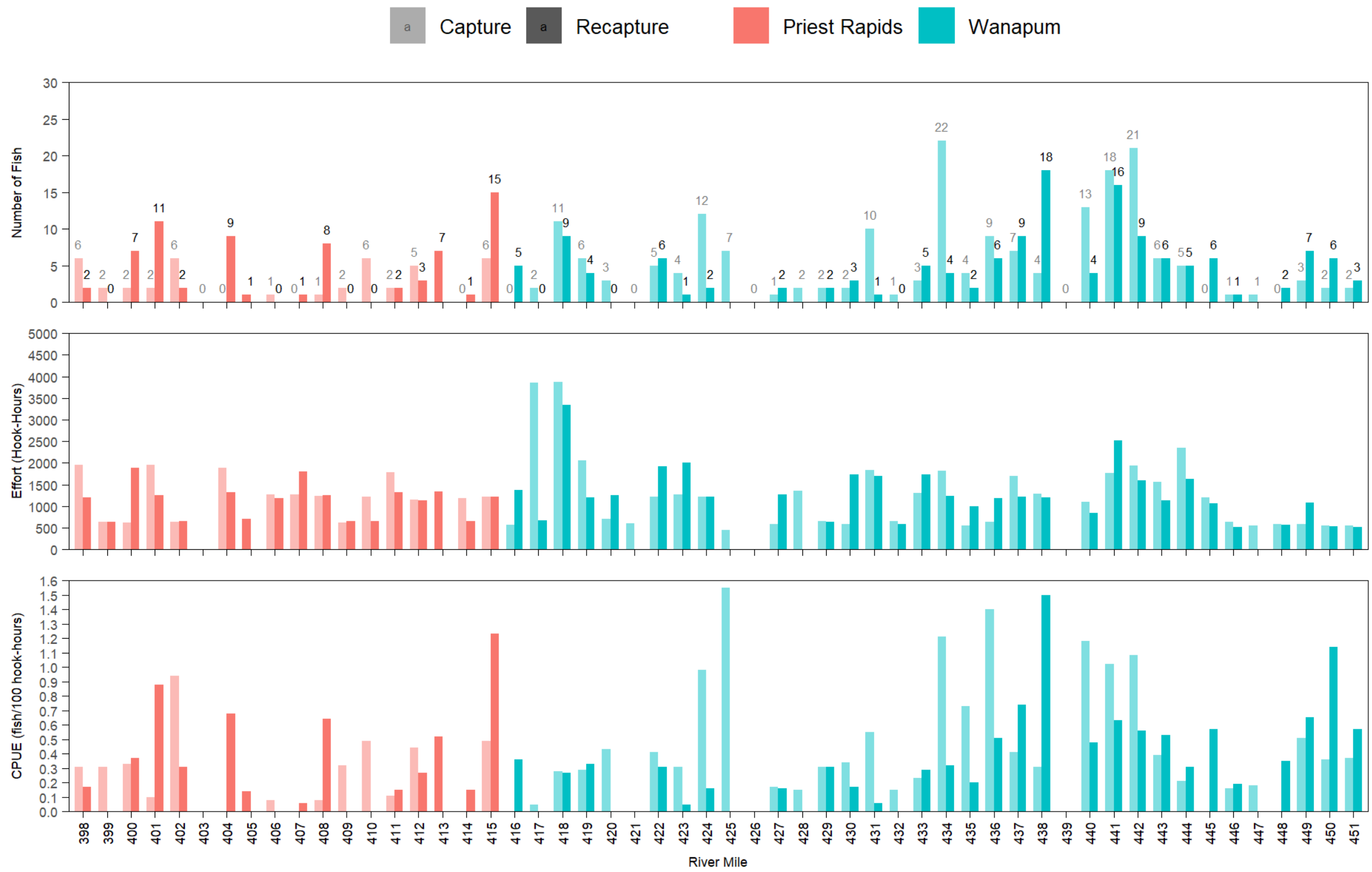

Figure 7 **White Sturgeon set line sampling catch, effort, and CPUE distribution by River Mile during the capture session (August 15 to 25) and recapture sessions (September 9 to 18) during the adult White Sturgeon indexing program.**

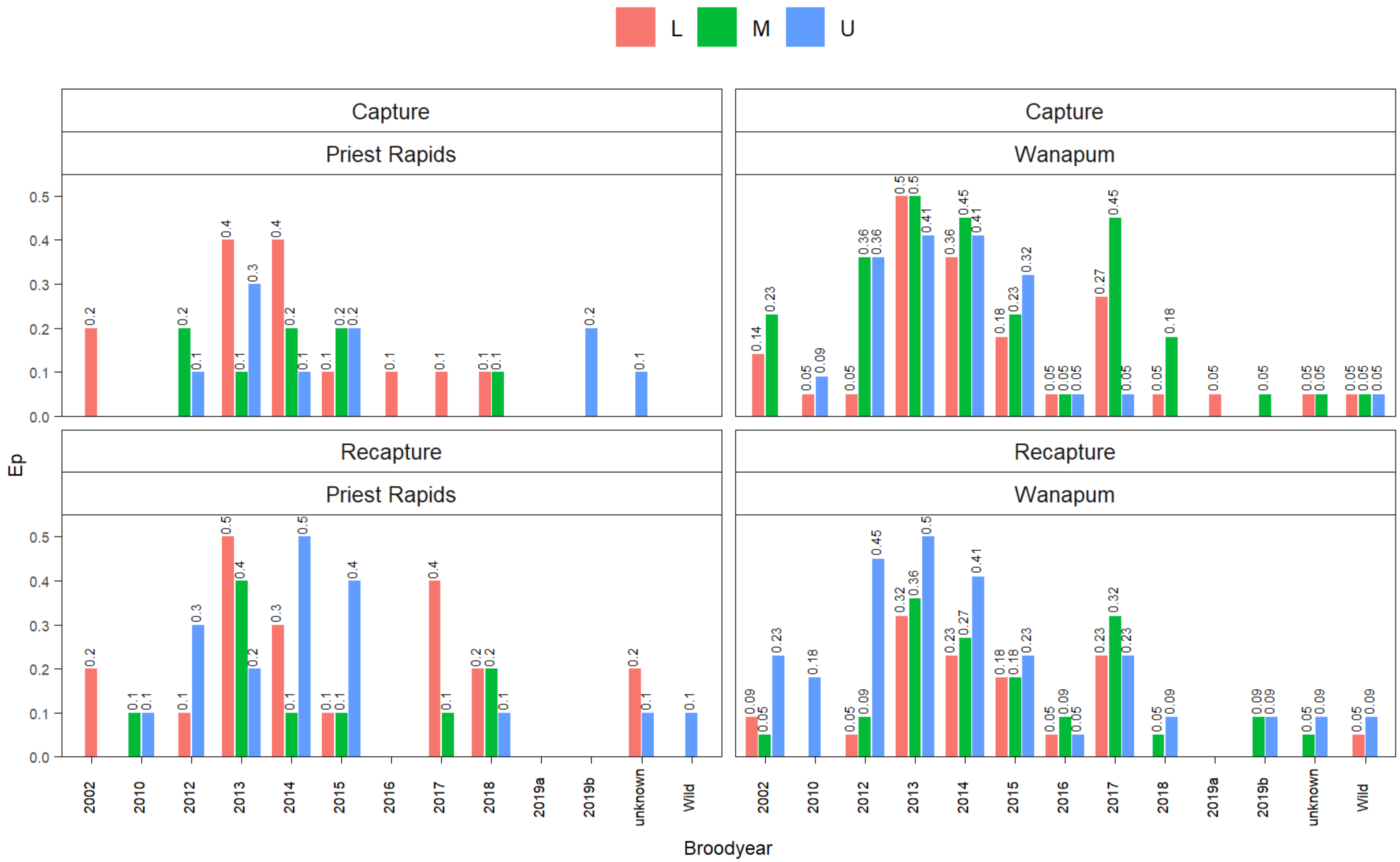

Figure 8 **Proportion of positive catch (Ep) of wild and hatchery White Sturgeon in lower, middle, and upper sections of Priest Rapids and Wanapum reservoirs recorded during the adult White Sturgeon indexing program, August 16 to September 18, 2021.**

In Priest Rapids reservoir during the capture session, the highest Eps recorded in the lower section were for the 2013BY and 2014BY (Figure 8). The 2002BY were also captured in the lower section of Priest Rapids reservoir. In the middle section, the highest Eps were recorded for 2012BY, 2013BY, and 2015BY. In the upper section, the highest Eps were recorded for the 2013BY, 2015BY, and the 2019BYb. During the recapture session in Priest Rapids reservoir, the highest Eps in the lower section were recorded for the 2013BY, 2014BY, and the 2017BY. The 2002BY were also captured in the lower section of Priest Rapids reservoir during the recapture session. In the middle section, the highest Eps during the recapture session were for the 2013BY and 2018BY. In the upper section, the highest Eps recorded were for the 2014BY, with slightly lower Eps recorded for the 2015BY, 2012BY, and 2013BY. Evidence of wild fish were also recorded in the upper section of Priest Rapids reservoir during the recapture session. In general, Eps were higher during the recapture session than during the capture session.

In Wanapum reservoir during the capture session, Eps were slightly higher in the middle section compared to the lower and upper sections for most brood years. The highest Eps recorded in the lower section were associated with the 2013BY, 2014BY, and 2017BY. High Eps were also recorded for the 2015BY and 2002BY in the lower section of Wanapum reservoir. In the middle section, high Eps were recorded for 2013BY, 2014BY, and 2017BY, with slightly lower Eps recorded for the 2012BY, 2002BY, and 2015BY. The Ep for the 2017BY in the middle section substantially exceeded Eps recorded in the lower and upper section for that brood year. In the upper section, the highest Eps were recorded for the 2013BY, 2014BY, 2012BY, and 2015BY. During the capture session, the 2002BY were captured in the lower and middle sections but not in the upper section. During the recapture session in Wanapum reservoir, Eps were generally lower compared to the capture session, with slightly higher Eps recorded in the upper section compared to the middle and lower sections for most brood years. The highest Eps in the lower section were recorded for the 2013BY, 2014BY, and the 2017BY. In the middle section, the highest Eps during the recapture session were for the 2013BY and 2017BY. In the upper section, the highest Eps recorded were associated with the 2013BY, 2012BY and 2014BY. The upper section also recorded higher Eps for the wild fish, 2002BY, and 2010BY compared to the middle and lower sections.

3.4.3 Adult Indexing White Sturgeon Size Distribution

In total, 436 individual White Sturgeon were captured and measured for fork length (FL) during the 2021 adult White Sturgeon indexing program. These fish ranged from 45.5 to 164.0 cm FL (mean = 77.8 cm FL; n = 110; Table 7) in Priest Rapids reservoir and from 37.5 to 252.0 cm FL (mean = 86.3 cm FL; n = 326) in Wanapum reservoir.

In the PRPA, large wild fish (i.e., fish >150 cm FL) and the 2002BY were considered as adult fish, while the 2010BY were considered as subadult fish. In Priest Rapids reservoir, low numbers of large 2002BY were captured that ranged from 127.0 to 164 cm FL (mean = 149.2 cm FL; n = 4) as well as low numbers of 2010BY that ranged from 89.0 to 159 cm FL (mean = 124.1 cm FL; n = 5). A single subadult wild fish 98 cm FL in length was captured in Priest Rapids reservoir and, assuming the fish was not entrained from upstream, suggests that natural recruitment still occurs in Priest Rapids reservoir. In Wanapum reservoir, the 2002BY ranged from 116.5 to 184.0 cm FL (mean = 156.6 cm FL; n = 16). The 2010BY captured in Wanapum reservoir were not as large as those caught in Priest Rapids reservoir and ranged from 61.5 to 134.0 cm FL (mean = 100.0 cm FL; n = 9). Although few in number, wild fish in

Wanapum reservoir were the largest fish captured during the assessment and ranged from 148.0 to 252.0 cm FL (mean = 198.6 cm FL; n = 7).

The length-frequency histograms of brood years 2010BY through 2019BY captured in Priest Rapids and Wanapum reservoirs exhibited substantial overlap among brood years. Similar size ranges of fish and capture frequency were generally evident for most brood years in both the capture and recapture sessions. In Priest Rapids reservoir, variation in the percent capture frequency of size classes within a given brood year was attributed to low sample size rather than an indication of a predominant size class in the brood year (Figure 9). The 2013BY exhibited a distinct bimodal length-frequency distribution around median size classes between 50.0 and 59.9 cm FL and 100 to 109.9 cm FL; however, this bimodal distribution was likely an artefact of low sample size. In Wanapum reservoir, the length-frequency distributions suggest a predominant size class in the 2013BY and 2014BY (i.e., between 70.0 and 99.9 cm FL) and the 2017BY (i.e., between 60.0 and 69.9 cm FL; Figure 10). The absence of a predominant size class in other brood years was attributed to low catch numbers; however, a predominant size class was not evident in the 2012BY even though 42 fish were captured.

Weights recorded for fish in each brood year for the combined capture and recapture sessions exhibited similar trends for both reservoirs and provided additional insight into differences in growth among brood years (Table 8). In both reservoirs, the 2012BY on average weighed less (mean = 4,611 g; SD = ±3,636 g; n = 53) than the younger 2013BY (mean = 5,543 g; SD = ±2,993 g; n = 119). Although the 2010BY were only captured in low numbers, a substantial increase in the weight of the 2010BY (mean = 11,413 g; SD = ±9,380 g; n = 14) compared to the weight of the 2012BY and 2013BY, indicates that the 2010BY experienced substantial growth in the last two to three years. This difference in growth was less evident based on change in fork length as these brood years exhibited substantial overlap in length-frequency. The adult 2002BY (mean = 31,285; SD = ±10,495 g; n = 20) and adult wild fish (mean = 68,586 g; SD = ±33,205 g; n = 7) overlapped in range; however, the largest wild fish (129,000 g) was more than double the weight of the largest 2002BY fish.

Figure 9 **Length-frequency distribution of White Sturgeon caught in Priest Rapids reservoir during the Capture and Recapture sessions during the 2021 adult indexing program.**

Figure 10 Length-frequency distribution of White Sturgeon caught in Wanapum reservoir during the Capture and Recapture sessions during the 2021 adult indexing program.

Table 7 Fork length (cm) of White Sturgeon captured during set line sampling in Priest Rapids and Wanapum reservoirs during adult White Sturgeon indexing in the PRPA from August 16 to September 18, 2021. The FL recorded during first capture was used for individuals captured more than once during the survey.

Program	BY	Priest Rapids					Wanapum					All				
		n	mean	SD	min	max	n	mean	SD	min	max	n	mean	SD	min	max
CRITFC	**2002**	4	**149.2**	17.7	127	164	16	**156.6**	16.3	116.5	184.0	20	**155.1**	16.4	116.5	184.0
Chelan PUD	**2010**	-	-	-	-	-	1	**132.0**	-	132.0	132.0	1	**132.0**	-	132.0	132.0
	2012	-	-	-	-	-	1	**109.0**	-	109.0	109.0	1	**109.0**	-	109.0	109.0
	2013	-	-	-	-	-	1	**88.0**	-	88.0	88.0	1	**88.0**	-	88.0	88.0
	2014	-	-	-	-	-	1	**81.0**	-	81.0	81.0	1	**81.0**	-	81.0	81.0
	2016	-	-	-	-	-	1	**59.5**	-	59.5	59.5	1	**59.5**	-	59.5	59.5
Douglas PUD	**2015**	-	**-**	-	-	-	1	**76.5**	-	76.5	76.5	1	**76.5**	-	76.5	76.5
Grant PUD	**2010**	5	**124.1**	25.9	89.0	159.0	9	**100.0**	21.8	61.5	134.0	14	**108.6**	25.4	61.5	159.0
	2012	12	**77.1**	19.7	54.0	131.0	41	**83.7**	22.3	47.0	125.0	53	**82.2**	21.8	47.0	131.0
	2013	31	**83.2**	24.5	45.5	124.0	89	**88.5**	14.0	50.5	116.0	120	**87.2**	17.4	45.5	124.0
	2014	20	**70.0**	16.3	48.5	100.0	63	**80.7**	13.3	48.5	107.0	83	**78.1**	14.7	48.5	107.0
	2015	13	**64.6**	12.0	49.0	87.0	30	**77.5**	12.9	51.5	100.5	43	**73.6**	13.9	49.0	100.5
	2016	1	**86.0**	-	86.0	86.0	8	**69.9**	8.6	60.5	85.0	9	**71.7**	9.7	60.5	86.0
	2017	7	**63.9**	9.0	51.0	75.0	37	**61.2**	7.4	44.5	76.0	44	**61.7**	7.6	44.5	76.0
	2018	9	**53.2**	4.9	46.0	60.0	9	**49.2**	6.5	37.5	56.0	18	**51.2**	6.0	37.5	60.0
	2019a	-	-	-	-	-	1	**41.5**	-	41.5	41.5	1	**41.5**	-	41.5	41.5
	2019b	2	**50.2**	6.0	46.0	54.5	5	**51.7**	7.2	42.5	60.0	7	**51.3**	6.4	42.5	60.0
Unknown[1]	**Unknown**	5	**77.6**	26.3	45.5	103.0	5	**97.5**	20.4	70.5	126.0	10	**87.6**	24.6	45.5	126.0
Wild	**Wild**	1	**98.0**	-	98	98	7	**198.6**	31.7	148.0	252.0	8	**186.1**	46.1	98.0	252.0
All sturgeon	**All**	110	**77.8**	27.2	45.5	164.0	326	**86.3**	30.2	37.5	252.0	436	**84.1**	29.6	37.5	252.0

[1]Considered to be of hatchery origin based either on the presence of a PIT tag, marks, or substantial fin deformity, but brood year, source, or stocking location data are unknown.

Table 8 Weight (g) of White Sturgeon captured during set line sampling in Priest Rapids and Wanapum reservoirs during adult White Sturgeon indexing in the PRPA form August 16 to September 18, 2021. The weight recorded during first capture was used for individuals captured more than once during the survey.

Program	BY	Priest Rapids					Wanapum					All				
		n	mean	SD	min	max	n	mean	SD	min	max	n	mean	SD	min	max
CRITFC	**2002**	4	**25,225**	7,805	14,700	31,200	16	**32,799**	10,728	9,790	52,200	20	**31,285**	10,495	9,790	52,200
Chelan PUD	**2010**	-	-	-	-	-	1	**24,500**	-	24,500	24,500	1	**24,500**	-	24,500	24,500
	2012	-	-	-	-	-	1	**8,905**	-	8,905	8,905	1	**8,905**	-	8,905	8,905
	2013	-	-	-	-	-	1	**4,480**	-	4,480	4,480	1	**4,480**	-	4,480	4,480
	2014	-	-	-	-	-	1	**4,750**	-	4,750	4,750	1	**4,750**	-	4,750	4,750
	2016	-	-	-	-	-	1	**1,180**	-	1,180	1,180	1	**1,180**	-	1,180	1,180
Douglas PUD	**2015**	-	-	-	-	-	1	**2,960**	-	2,960	2,960	1	**2,960**	-	2,960	2,960
Grant PUD	**2010**	5	**16,893**	12,788	4,865	38,350	9	**8,369**	5,658	1,505	21,300	14	**11,413**	9,380	1,505	38,350
	2012	12	**3,376**	3,063	1,020	12,530	41	**4,972**	3,743	605	13,170	53	**4,611**	3,636	605	13,170
	2013	31	**5,199**	4,046	550	14,600	88	**5,664**	2,540	910	11,440	119	**5,543**	2,993	550	14,600
	2014	20	**2,549**	1,615	655	5,750	63	**4,008**	1,827	695	7,920	83	**3,657**	1,877	655	7,920
	2015	13	**2,080**	1,369	800	4,870	30	**3,652**	1,808	850	7,345	43	**3,177**	1,824	800	7,345
	2016	1	**4,850**	-	4,850	4,850	8	**2,601**	1,016	1,395	4,090	9	**2,851**	1,210	1,395	4,850
	2017	7	**1,799**	816	855	3,250	37	**1,541**	602	580	2,980	44	**1,582**	637	580	3,250
	2018	9	**1,052**	278	665	1,520	9	**853**	276	365	1,165	18	**953**	288	365	1,520
	2019a	-	-	-	-	-	1	**445**	-	445	445	1	**445**	-	445	445
	2019b	2	**685**	297	475	895	5	**963**	354	430	1,425	7	**884**	341	430	1,425
Unknown[1]	**Unknown**	5	**3,949**	2,876	605	7,125	5	**7,295**	4,057	2,595	12,918	10	**5,622**	3,755	605	12,918
Wild	**Wild**	1	**7,030**	-	7,030	7,030	7	**68,586**	33,205	23,100	129,000	8	**60,891**	37,666	7,030	129,000
All sturgeon	**All**	110	**4,728**	6,353	475	38,350	325	**7,134**	12,514	365	129,000	435	**6,526**	11,320	365	129,000

[1]Considered to be of hatchery origin based either on the presence of a PIT tag, marks, or substantial fin deformity, but brood year, source, or stocking location data are unknown.

3.4.4 Adult White Sturgeon Reproductive Status

Surgical inspection of select wild and 2002BY adult fish captured in Priest Rapids and Wanapum reservoirs identified fish in various states of reproductive maturity. In total, 12 2002BY adult fish were surgically inspected and of these, three ripe females (i.e., F4) and five ripe males (i.e., M2) were identified (Table 9). Of these ripe fish, the females ranged in size from 150.5 to 168.0 cm FL (mean = 157.2 cm FL; n = 3) and the males ranged in size from 145.0 to 175.5 cm FL (mean = 163.3 cm FL; n = 5). Of the four wild fish inspected, three were identified as mature males (i.e., M2), that ranged in size from 190.0 to 212.0 cm FL (mean = 200.5 cm FL; n = 3), and one was a large developing female (i.e., F2; 252.0cm FL). The presence of new oocytes and no altricial oocytes suggested that this female sturgeon did not spawn in the previous season but may have spawned within the last three to five years.

Table 9 Reproductive status and fork length (cm) of adult wild and 2002BY White Sturgeon captured during set line sampling in Wanapum and Priest Rapids reservoirs during adult White Sturgeon indexing in the PRPA, August 16 to September 18, 2021.

Adult Origin	Reproductive Status	Fork Length (cm)				
		n	mean	SD	min	max
2002BY	**F1**	1	**158.0**	-	158.0	158.0
2002BY	**F4**	3	**157.2**	9.5	150.5	168.0
2002BY	**M1**	3	**174.0**	10.5	163.0	184.0
2002BY	**M2**	5	**163.3**	11.9	145.0	175.5
Wild	**F2**	1	**252.0**	-	252.0	252.0
Wild	**M2**	3	**200.5**	11.0	190.0	212.0

3.4.5 Adult White Sturgeon Indexing Gear Performance

During adult White Sturgeon indexing, most 2010BY to 2019BY fish (47.0%; n = 195) were captured by 12/0 hooks, the smallest hook size (Table 10), with lower catches recorded on 14/0 hooks (32.8%; n = 136), and 16/0 hooks (20.2%; n = 84). The 12/0 hooks successfully captured both small and large fish. Catch on larger hook sizes is expected to increase as the hatchery fish grow and recruit to these hook sizes.

Table 10 Capture of White Sturgeon by hook size in the Priest Rapids Project area during adult indexing studies, August 16 to September 18, 2021.

Hook Size	2010-2019BY Catch Fork Length (cm)				
	n	**mean**	**SD**	**min**	**max**
12/0	195	72	18.5	37.5	134.0
14/0	136	80.2	19.0	41.5	159.0
16/0	84	91.6	18.9	51.5	136.5
	415				

3.4.6 Adult Indexing White Sturgeon Abundance Estimates

Out of the set of POPAN models constructed for mark-recapture data collected in Wanapum and Priest Rapids reservoirs, the model with the best support (as indicated by the lowest QAICc) estimated survival as an additive function of group (wild, 2002BY, and 2010BY-2019BY) and whether the cull / fishery occurred between sampling occasions. This model's recapture probability was expressed as an additive function of group and sampling occasion, while the probability of entry was a trend of time, and superpopulation was a function of group.

Outside of the period of the cull / fishery, the survival estimates based on the best-supported POPAN model ranged between 0.903 (for the 2002BY in 2010) to 0.988 (2010BY–2019BY in 2018; Figure 11). During the cull / fishery period, survival was lower for all three groups of fish, with values of 0.370 for 2002BY, 0.500 for wild fish, and 0.844 for 2010BY-2019BY. Probabilities of recapture were generally highest for the 2002BY, ranging from 0.079 in 2012 to 0.174 in 2021 (Figure 12), and generally lowest for 2010BY-2019BY, ranging from 0.028 in 2012 to 0.067 in 2021. The probability of entry for 2010BY-2019BY fish was estimated to be 0.223, 0.317, and 0.445 in 2015, 2018, and 2021, respectively. The respective 95% confidence intervals were 0.093–0.446 in 2018, 0.274–0.364 in 2018, and 0.242–0.676 in 2021.

Estimates of the Wanapum reservoir 2002BY population decreased from 3,190 fish (95% CI = 2,701–3,769) in 2010 to 86 fish (95% CI = 40–187) in 2021 (Table 11; Figure 13), following a strong reduction in numbers due to the 2015–2016 cull / fishery. Similarly, the estimated population abundance of wild fish in Wanapum reservoir declined from 978 fish (95% CI = 577–1,657) in 2010 to 82 fish (95% CI = 31–218) in 2021 (i.e., 8% of the 2010 population estimate). On the other hand, the population estimates of the 2010BY-2019BY increased from 34 fish (95% CI = 7–158) in 2012 to 4,533 fish (95% CI = 2,560–8,027) in 2021, as these fish began recruiting to the adult sampling gear.

In Priest Rapids reservoir, the 2002BY population was estimated at 1,615 fish (95% CI = 1,367–1,908) in 2010, with a subsequent reduction to 22 fish (95% CI = 10–47) in 2021. The wild population in Priest Rapids reservoir was estimated at 244 fish (95% CI = 144–414) in 2010, with a reduction to 12 fish (95% CI = 4–31) in 2021, or a reduction to 4.9% of the 2010 population. Similar to Wanapum reservoir, the population estimates of the 2010BY-2019BY increased from 34 fish (95% CI = 7–158) in 2012 to 1,571 fish (95% CI = 887–2,782) in 2021, as these fish recruit to the adult sampling gear.

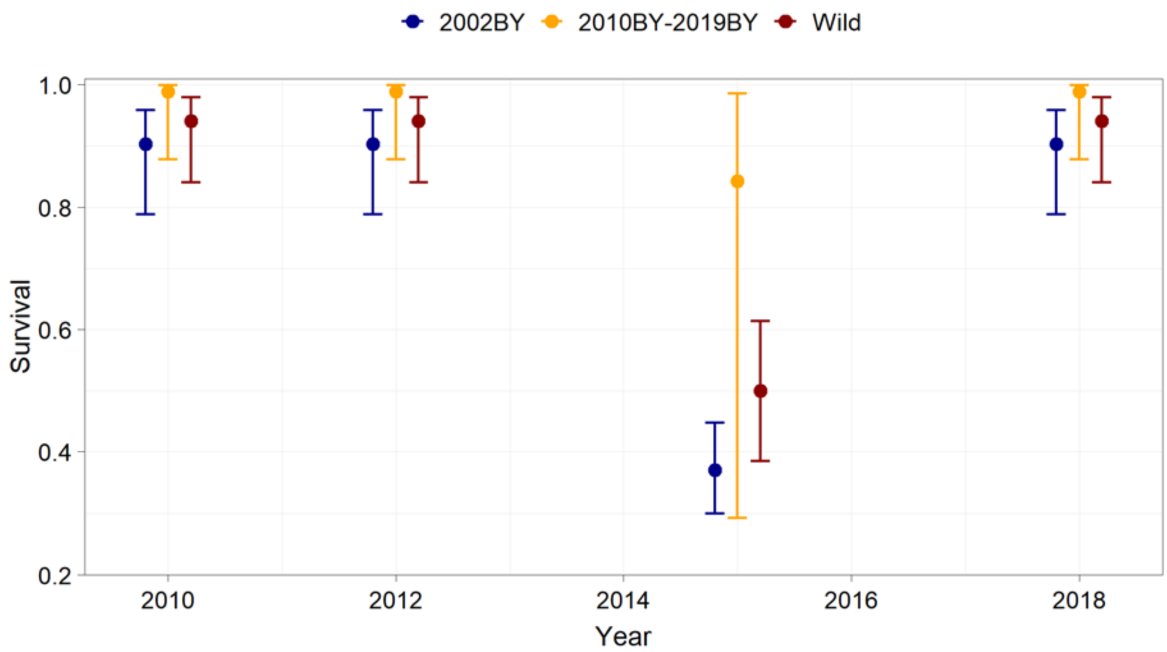

Figure 11 **Survival estimates for POPAN models of wild, 2002BY, and 2010BY-2019BY White Sturgeon captured in Priest Rapids and Wanapum reservoirs during adult White Sturgeon indexing in 2010, 2012, 2015, 2018, and 2021.**

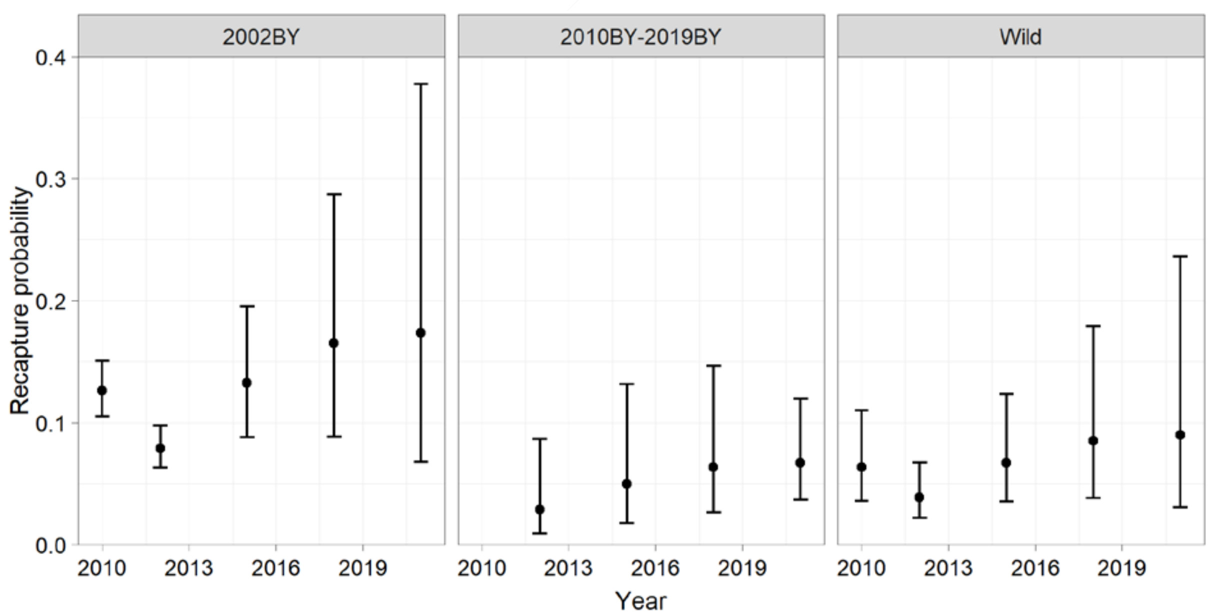

Figure 12 **Estimates of probability of recapture for POPAN models of wild, 2002BY, and 2010BY-2019BY White Sturgeon captured in Wanapum and Priest Rapids reservoirs during adult White Sturgeon indexing in 2010, 2012, 2015, 2018, and 2021.**

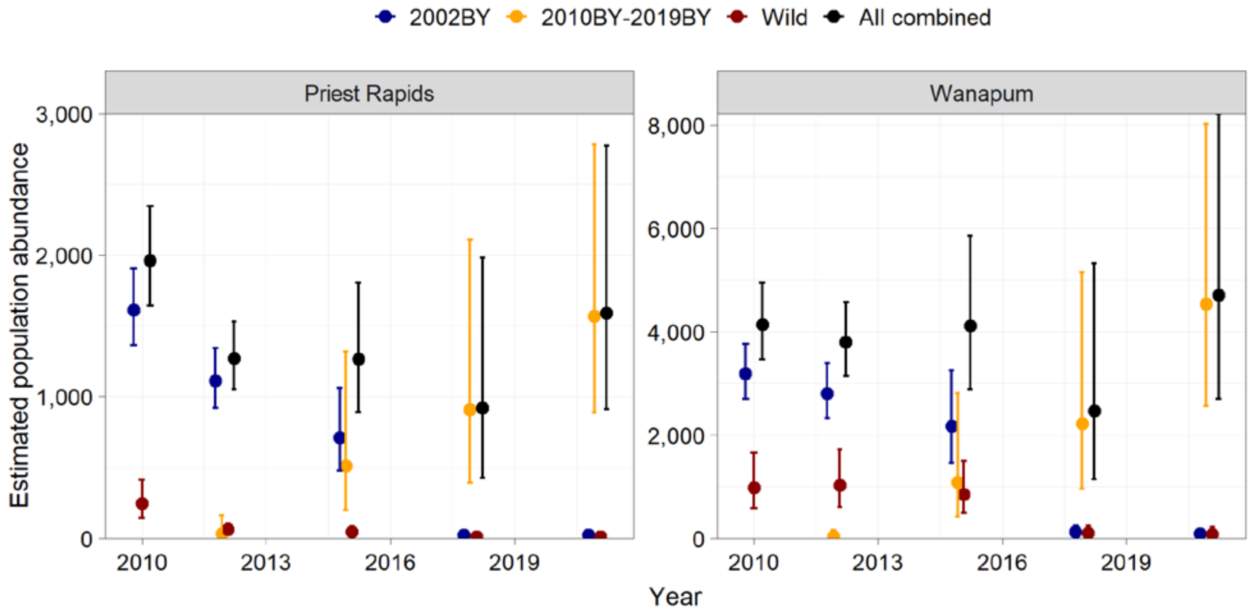

Figure 13 **Estimates of population abundance of wild, 2002BY, and 2010BY-2019BY White Sturgeon captured in Wanapum and Priest Rapids reservoirs during adult White Sturgeon indexing in 2010, 2012, 2015, 2018, and 2021, by reservoir, year, and group.**

Table 11 Estimated population abundance of 2002BY Hatchery, 2010BY-2019BY, and wild White Sturgeon in the Priest Rapids Project area in 2010, 2012, 2015, and 2021; values in parentheses are 95% confidence intervals.

Reservoir	Year	Abundance estimates			
		2002BY Hatchery	2010BY-2019BY hatchery	Wild	Total
Wanapum	2010	3,190 (2,701-3,769)	---	978 (577-1,657)	4,133 (3,454-4,945)
	2012	2,806 (2,325-3,386)	34 (7-158)	1,020 (607-1,715)	3,796 (3,148-4,577)
	2015	2174 (1,454-3,251)	1,086 (420-2,805)	853 (486-1,496)	4,112 (2,888-5,855)
	2018	125 (66-236)	2,221 (959-5,142)	100 (41-242)	2,469 (1,145-5,324)
	2021	86 (40-187)	4,533 (2,560-8,027)	82 (31-218)	4,714 (2,704-8,219)
Priest Rapids	2010	1,615 (1,367-1,908)	---	244 (144-414)	1,964 (1,641-2,350)
	2012	1,112 (921-1,342)	34 (7-158)	61 (36-103)	1,270 (1,053-1,531)
	2015	710 (475-1,061)	511 (198-1,320)	47 (27-82)	1,268 (890-1,805)
	2018	22 (12-42)	910 (393-2,107)	12 (5-30)	920 (427-1,985)
	2021	22 (10-47)	1571 (887-2,782)	12 (4-31)	1,591 (912-2,773)

3.5 Juvenile White Sturgeon Population Indexing

Juvenile White Sturgeon population indexing in Priest Rapids and Wanapum reservoirs was conducted from September 27 to October 23, 2021. The GRTS study design assigned sample sites in equal numbers to each of the three defined sections (i.e., lower, middle, and upper sections) in Priest Rapids and Wanapum reservoirs (Table 12).

The mean depth and the range of depths sampled was greater in Wanapum reservoir (mean = 20.2 m; range = 7.0 to 39.9 m) than in Priest Rapids reservoir (mean = 11.0 m; range = 2.4 to 24.7 m). Mean water depths at sample sites in the upper sections of both Wanapum and Priest Rapids reservoirs were slightly less compared to mean depths recorded in the lower and middle sections. At some sample sites, minimum water depths less than the bathymetric minimum depth criteria for each reservoir (i.e., 15 m in Wanapum reservoir and 6 m in Priest Rapids reservoir) were recorded due to variation in bathymetry over the length of the set line.

All set lines were intended to be deployed overnight for approximately 24 hours, but actual deployment duration varied between 15.8 and 24.7 hours. Sample durations less than 24 hours were due to variations in deployment and retrieval order.

Table 12 Details of GRTS sample site distributions among Wanapum and Priest Rapids reservoir sections, areal extent of reservoirs sections, estimates of sampling intensity, and set line sample depths and durations recorded during the juvenile White Sturgeon indexing program, September to October 23, 2021.

	Reservoir							
	Priest Rapids (6 m Bathymetric Contour)				Wanapum (15 m Bathymetric Contour)			
	Lower	Middle	Upper	All	Lower	Middle	Upper	All
Number of GRTS sites sampled per section	20	20	20	60	44	44	44	132
Sampling area (ha)	1,369	346	213	1,928	1,664	727	308	2,699
Samples/100 ha	2.2	8.7	14.1	4.7	5.4	12.4	29.2	10.0
Sample depths (m)								
mean	14.5	9.5	8.8	11.0	22.0	20.3	18.2	20.2
min	7.5	2.4	5.8	5.2	11.9	12.0	7.0	10.3
max	24.7	15.9	18.3	19.6	39.9	30.0	36.0	35.3
Sample duration (h)								
mean	21.2	21.0	22.0	21.4	20.5	19.1	19.2	19.6
min	19.8	18.2	19.9	19.3	18.2	15.8	16.1	16.7
max	22.8	22.2	23.7	22.9	22.8	22.2	24.7	23.2

3.5.1 2021 Juvenile White Sturgeon Indexing Catch

In total, 924 White Sturgeon were captured and processed during the juvenile White Sturgeon indexing program in Priest Rapids (n = 170) and Wanapum (n = 754) reservoirs (Figure 14; Table 13). These captures represented 903 individual fish. One fish was captured twice in Priest Rapids reservoir and 20 fish were captured twice in Wanapum reservoir. Incidental captures were primarily Northern Pikeminnow (*Ptychocheilus oregonensis*; n = 46 in Priest Rapids reservoir; n = 82 in Wanapum reservoir). Within Priest Rapids reservoir, incidental catch of Largescale Sucker (*Catostomus macrocheilus*; n = 1) and Channel Catfish (*Ictalurus punctatus;* n = 8) were also recorded.

In both reservoirs combined, the 2014BY (223 of 924 fish; 24%) and the 2014BY (153 of 924 fish; 17%) contributed the largest proportion to the total catch. Lesser numbers of 2017BY (106 of 924 fish; 12%), 2018BY (105 of 924; 12%), 2015BY (98 of 924 fish; 11%), 2012BY (82 of 924 fish; 9%) were captured in similar proportions, with the remaining brood years (i.e., 2002BY, 2010BY, 2016BY, 2018BY, 2019BYa, 2019BYb), unknown hatchery fish, and wild fish contributing the remainder of the total catch. The 2002BY (4 of 924 fish; <1%) and wild fish (9 of 924 fish; 1%), were captured in low numbers.

Entrainment of recently released hatchery fish (i.e., 2010BY and younger) was evident in the catch data of fish that were either originally released upstream of and then subsequently captured in the PRPA or were released in Wanapum reservoir and subsequently captured in Priest Rapids reservoir (Table 13). Low numbers of fish from 2010BY to 2018BY that were originally released in Rocky Reach reservoir (n = 8 fish) or Wells reservoir (n = 2 fish) were captured in Priest

Rapids (n = 1) and Wanapum (n = 9) reservoirs. Hatchery fish that were originally released in Wanapum reservoir and captured in Priest Rapids reservoir contributed a substantial proportion to the total catch (n = 66 of 170 fish; 39%) and the majority of the 2013BY captured in Priest Rapids reservoir (n =28 of 37 fish; 76%).

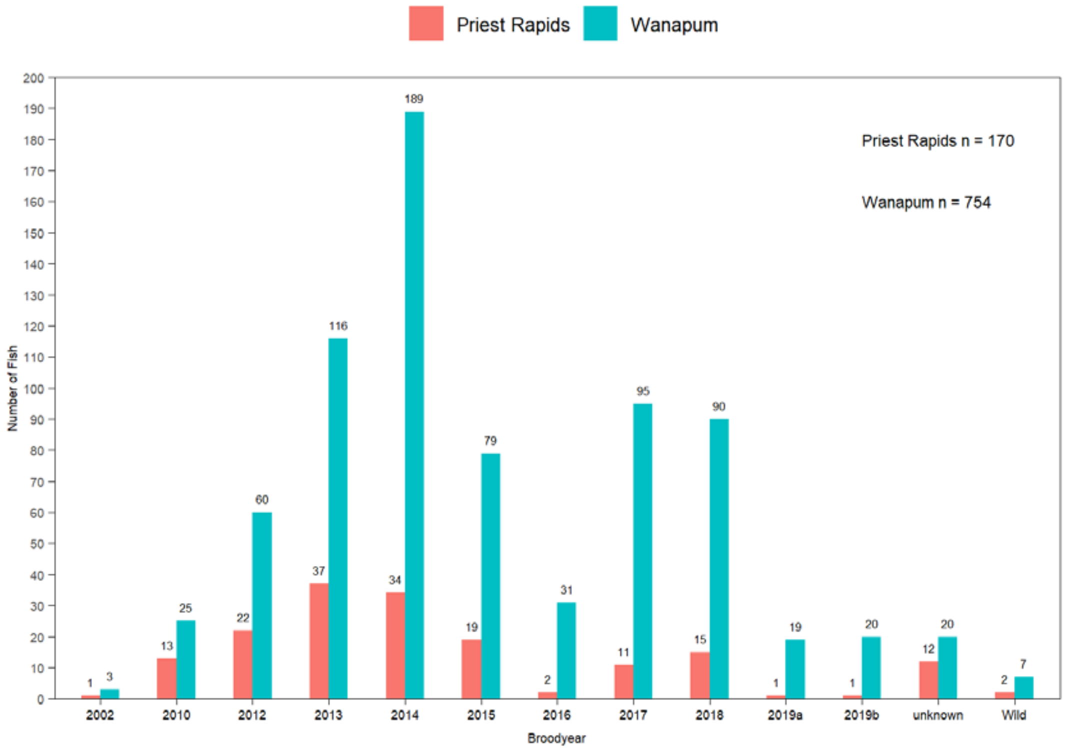

Figure 14 **Hatchery and wild White Sturgeon captured in the Priest Rapids Project area during the juvenile White Sturgeon indexing program, September 27 to October 23, 2021. The Unknown category represents fish suspected to be of hatchery origin but without a PIT tag to allow identified of origin and brood year.**

Table 13 Hatchery and wild White Sturgeon captured in the Priest Rapids Project area during the juvenile White Sturgeon indexing program, September 27 to October 23, 2021.

		Capture Reservoir		
Brood Year	Release Reservoir	Priest Rapids	Wanapum	Total
Upstream Releases				
2002	Rock Island	1	3	4
2010	Rocky Reach	1	-	1
2012	Rocky Reach	-	1	1
2014	Rocky Reach	-	4	4
2015	Rocky Reach	-	1	1
2018	Rocky Reach	-	1	1
2013	Wells	-	1	1
2015	Wells	-	1	1
PRPA Releases				
2010	Priest Rapids	8	-	8
	Wanapum	4	25	29
2012	Priest Rapids	17	-	17
	Wanapum	5	59	64
2013	Priest Rapids	9	-	9
	Wanapum	28	115	143
2014	Priest Rapids	19	-	19
	Wanapum	15	185	200
2015	Priest Rapids	10	-	10
	Wanapum	9	77	86
2016	Priest Rapids	1	-	1
	Wanapum	1	31	32
2017	Priest Rapids	8	-	8
	Wanapum	3	95	98
2018	Priest Rapids	15	-	15
	Wanapum	-	89	89
2019a	Wanapum	1	19	20
2019b	Priest Rapids	1	-	1
	Wanapum	-	20	20
Unknown[1]	Unknown	12	20	32
Wild	-	2	7	9
Total		170	754	924

[1]Considered to be of hatchery origin based either on the presence of a PIT tag, marks, or substantial fin deformity, but brood year, source, or stocking location data are unknown.

3.5.2 Catch Rates and Distribution

In total, 288,761 hook-hours of set line sample effort were expended during the 2021 juvenile White Sturgeon indexing program (Table 14). Overall, CPUE in the PRPA was 0.32 fish/100 hook-hours, with higher CPUE recorded in Wanapum reservoir (0.36 fish/100 hook-hours) than in Priest Rapids reservoir (0.22 fish/100 hook-hours). In Priest Rapids reservoir, the highest CPUE was recorded in the upper reservoir section (0.32 fish/100 hook-hours), followed by the lower section (0.18 fish/100 hook-hours), with the lowest CPUE recorded in the middle section (0.16 fish/100 hook-hours). In Wanapum reservoir, the highest CPUE was recorded in the upper reservoir section (0.51 fish/100 hook-hours), followed by the middle section (0.35 fish/100 hook-hours), with the lowest CPUE recorded in the lower section (0.22 fish/100 hook-hours).

The proportion of set lines that captured one or more fish (Ep) was higher in Wanapum reservoir than in Priest Rapids reservoir and changes in Ep between reservoir sections generally aligned with corresponding changes in CPUE (Figure 15). In Priest Rapids reservoir, the highest Eps were recorded in the upper (Ep = 0.60) and lower sections (Ep = 0.60), with substantially lower Ep recorded in the middle section (Ep = 0.33). In Wanapum reservoir, Eps in each reservoir section aligned with corresponding CPUE estimates for these sections, with the highest Ep recorded in the upper section (Ep = 0.83), followed by the middle section (Ep = 0.77), and were lowest in the lower section (Ep = 0.63).

Table 14 Total set line sample effort, catch, and CPUE in the Priest Rapids Project area during the juvenile White Sturgeon indexing program, September 27 to October 23, 2021.

Reservoir	Reservoir Section	Sample Effort (hook-hours)	Catch (Number of fish)				CPUE (Fish/100 hook-hours)			
			Wild	H-123LAD	2002BY	Total	Wild	H-123LAD	2002BY	Wild & Hatchery
Wanapum	Lower	73,888	2	162	2	166	0.003	0.22	0.003	0.23
	Middle	68,828	0	238	1	239	0.000	0.35	0.001	0.35
	Upper	69,099	5	344	0	349	0.007	0.50	0.000	0.51
	all	211,815	7	744	3	754	0.003	0.35	0.001	0.36
Priest Rapids	Lower	25,368	2	43	1	46	0.008	0.17	0.004	0.18
	Middle	25,130	0	40	0	40	0.000	0.16	0.000	0.16
	Upper	26,448	0	84	0	84	0.000	0.32	0.000	0.32
	all	76,946	2	167	1	170	0.003	0.22	0.001	0.22
PRPA	Total	288,761	9	911	4	924	0.003	0.32	0.001	0.32

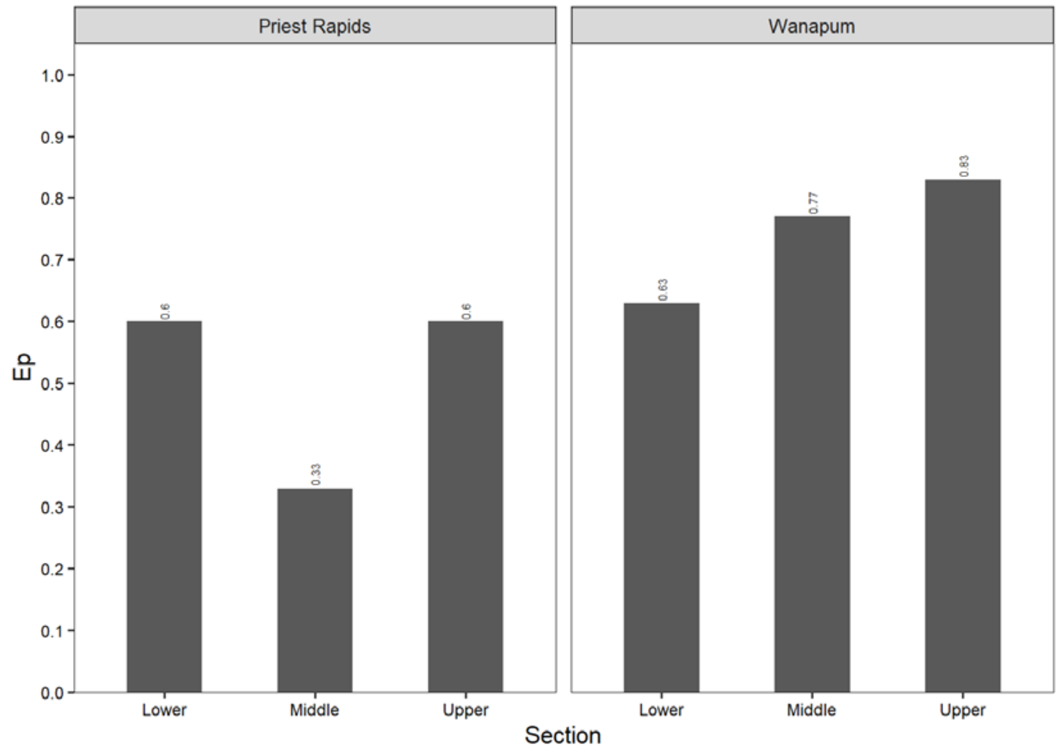

Figure 15 **Proportion of positive catches (Ep) recorded in the Priest Rapids Project area within the lower, middle, and upper section of each reservoir during the juvenile White Sturgeon indexing program, September 27 to October 23, 2021.**

In Priest Rapids reservoir, 44 of the 90 set lines deployed (49%) did not catch fish, with a higher proportion of zero-catch effort recorded in the middle section (67%) than in the lower (40%) and upper (40%) sections. In Wanapum reservoir, 69 of the 270 set lines deployed (26%) did not catch fish, with a higher proportion of zero-catch efforts recorded in the lower section of Wanapum reservoir (37%) than in the middle (23%) and upper (17%) sections of the reservoir (Figure 16). Due to the aggregatory tendencies of White Sturgeon, a small number of set lines caught a disproportionately high number of fish compared to the overall median catch of one fish per set line in Priest Rapids reservoir and two fish per set line in Wanapum reservoir. In Priest Rapids reservoir, approximately 4% of the set lines deployed (i.e., 4 of 90 set lines), captured between 12 and 22 fish, which equated to 41% of the total catch (69 of 170 fish). Three of four high-catch sites in Priest Rapids reservoir were in the upper section of the reservoir. The fourth high-catch site (20 fish captured) was in the middle section and accounted for 50% of the catch in the section. In Wanapum reservoir, fish were less aggregated, in that 4% of set lines deployed (12 of 270 set lines) captured between 10 and 22 fish, which contributed 20% to the total catch (150 of 754 fish).

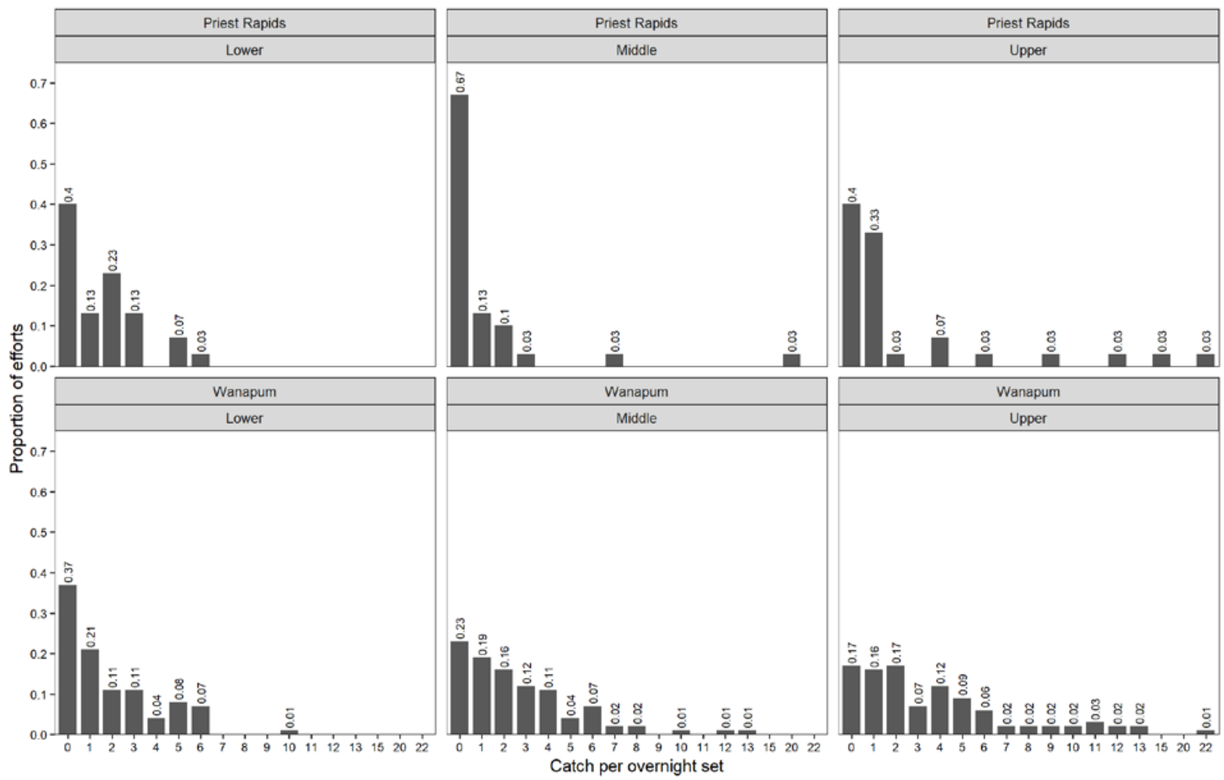

Figure 16 **Frequency histograms of White Sturgeon catch-per-overnight-set in the Priest Rapids Project Area during the juvenile White Sturgeon indexing program, September 27 to October 23, 2021.**

The GRTS unstratified unequal probability sample design distributed effort over the geographical area within each reservoir that encompassed the targeted minimum depth sample criteria (i.e., 15 m in Wanapum reservoir and 6 m in Priest Rapids reservoir). Histogram plots of catch, effort, and CPUE by River Mile indicated general areas within each reservoir where higher captures of White Sturgeon were encountered (Figure 17). The highest sample effort per River Mile was recorded in the lower section of each reservoir, nearer the forebays, where the river is widest; however, the GRTS sampling approach did result in localized areas of higher and lower sample effort throughout each reservoir. The distribution of sample effort was consistent with previous study years (Golder 2021).

In Priest Rapid reservoir, high CPUEs were recorded immediately upstream of Priest Rapids Dam near RM388 compared to other locations in the lower section. A large portion of the middle section was devoid of fish, with the highest CPUE recorded in the middle section at a localized area near RM408. In the upper section, the highest CPUEs were within two River Miles of the Wanapum Dam tailrace area near RM415.

In Wanapum reservoir, CPUE in the lower section was low throughout most of the section but increased near RM418 and near RM425. In the middle section, CPUE was uniformly low from RM428 to RM436, but increased substantially from RM437 to RM440. In the upper section, high CPUEs were recorded from RM441 to RM443, which encompasses a known holding area for White Sturgeon near RM442 (Golder 2016). The CPUE in the upper section decreased in the lower portion of the section between RM446 and RM449, but increased near RM450.

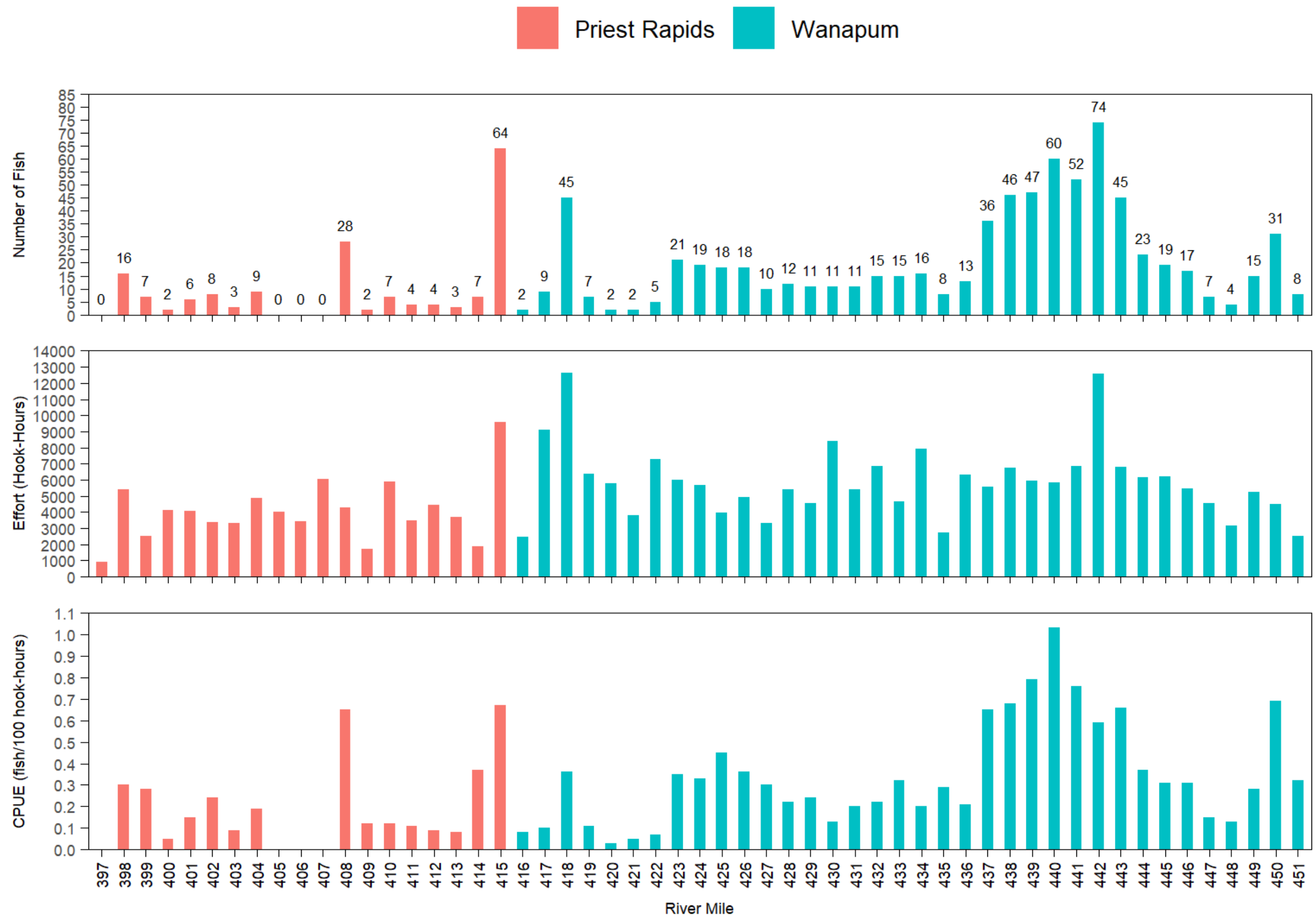

Figure 17 Juvenile White Sturgeon catch, effort, and CPUE distribution by River Mile in the Priest Rapids Project area, during the juvenile White Sturgeon indexing program from September 27 to October 23, 2021.

In Priest Rapids reservoir, based on the distribution of fish by brood year based on Ep, fish from each brood year release were recorded in the lower section of Priest Rapids reservoir, with a slightly higher Ep associated with the 2013BY than other brood years (Figure 18). In addition, 2002BY, 2016BY, and wild fish were captured in the lower section and not in the middle or upper sections. In the middle section, generally low Eps were recorded with the highest Eps associated with the 2013BY and 2018BY. In the upper section, the highest Eps, in decreasing order, were associated with the 2014BY, 2013BY, 2012BY, and 2010BY.

In Wanapum reservoir, fish from each brood year, wild fish, and unknown hatchery fish were recorded in the lower section; however, the Eps of the 2014BY and 2013BY were higher than other brood years. In the middle section, the highest Eps in decreasing order were recorded for 2014BY, 2018BY, 2017BY, 2013BY, and 2015BY. The Eps of these same brood years in the upper section had a similar order and magnitude as in the middle section; however, the Ep of 2012BY in the upper reservoir section was higher than in the middle and lower sections and suggests a preference for the upper reservoir section by the 2012BY. Out of all the brood year releases, the 2014BY followed by the 2013BY were the most broadly dispersed and captured in moderate numbers in all sections of the reservoir.

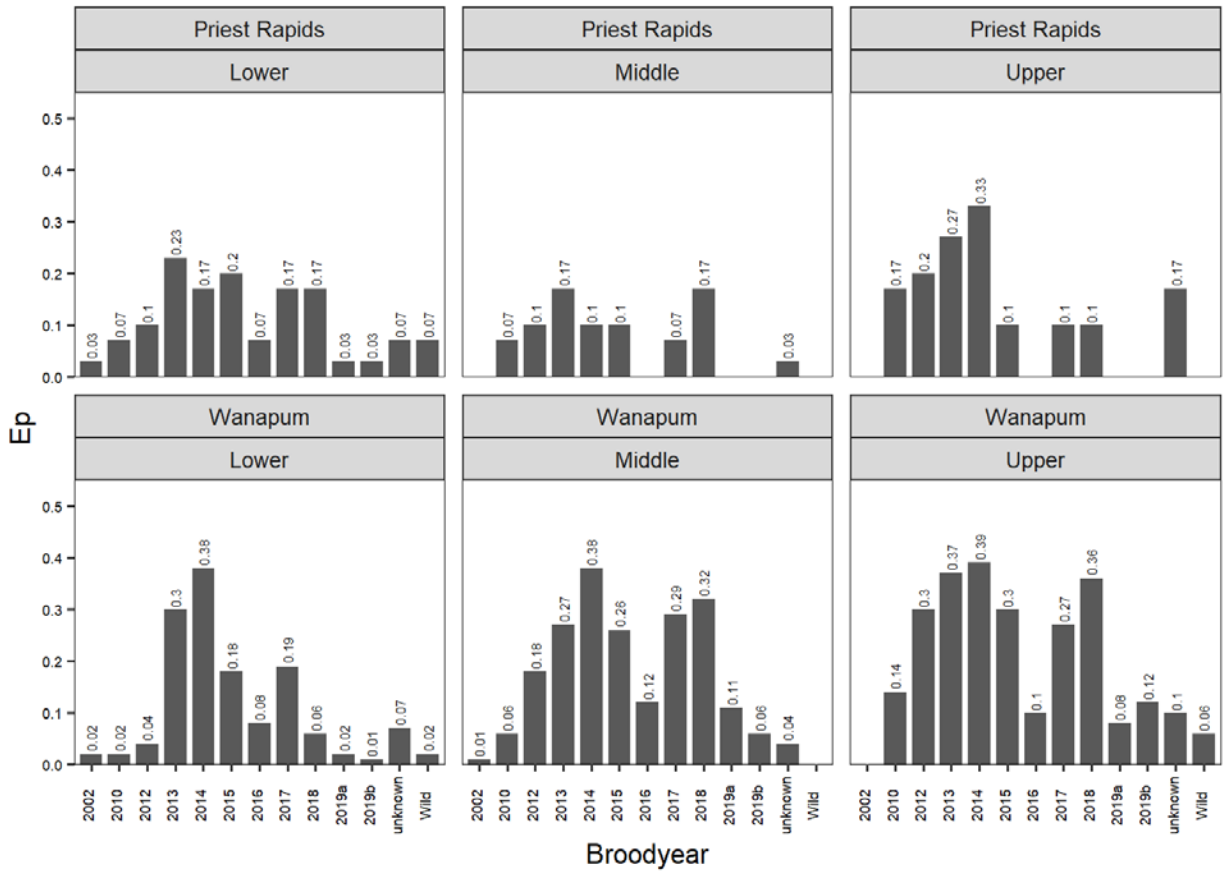

Figure 18 **Proportion of positive catch (Ep) of wild and hatchery White Sturgeon in lower, middle, and upper sections of Priest Rapids and Wanapum reservoirs recorded during the juvenile White Sturgeon indexing program, September 27 to October 23, 2021.**

3.5.3 White Sturgeon Size Distribution

In total, 902 individual White Sturgeon were captured and measured for fork length (FL) during the 2021 juvenile White Sturgeon indexing program in the PRPA. These fish ranged from 42.0 to 146.0 cm FL (mean = 72.0 cm FL; n = 169; Table 15) in Priest Rapids reservoir and from 34.5 to 155.0 cm FL (mean = 72.2 cm FL; n = 733) in Wanapum reservoir.

The length-frequency distributions of brood years 2010BY through 2019BY captured in Priest Rapids and Wanapum reservoirs exhibited substantial overlap among brood years. In Priest Rapids reservoir, similar size ranges of fish and capture frequency were generally evident for most brood years. In general, the variation in the percent capture frequency of size classes within a given brood year was attributed to low sample size rather than an indication of a predominant size class in the brood year (Figure 19). The exception to this assumption may be the 2014BY that exhibit a distinct increase in percent frequency around median size classes between 50.0 and 59.9 cm FL. In Wanapum reservoir, the length-frequency distributions suggest a predominant size class in the 2013BY and 2014BY (i.e., between 70.0 and 99.9 cm FL), the 2015BY (i.e., between 70.0 and 89.9 cm FL), the 2017BY (i.e., between 40.0 and 59.9 cm FL) and the 2018BY (i.e., between 40.0 and 49.9 cm FL; Figure 20). Low numbers of wild fish captured either in Priest Rapids or Wanapum reservoirs ranged from 47.5 to 111.0 cm FL (mean = 80.6 cm FL; n = 8). Based on their size, these wild fish were considered either juveniles or subadults and likely indicate that natural recruitment still occurs in both reservoirs.

Weights recorded for fish in each brood year exhibited a similar trend in both reservoirs and provided additional insight on growth differences among brood years (Table 16). Consistent with results of 2021 adult White Sturgeon indexing (Section 3.3.2), in both reservoirs, the mean weight of the 2012BY (mean = 4,408 g; SD±3,009 g; n = 78) was lower than the younger 2013BY (mean = 5,177 g; SD±2,983 g; n = 151). The greater mean weight of the 2010BY (mean = 6,215 g; SD±5,508 g; n = 36) suggests that the reduced growth of the 2012BY is likely a real attribute of that brood year population.

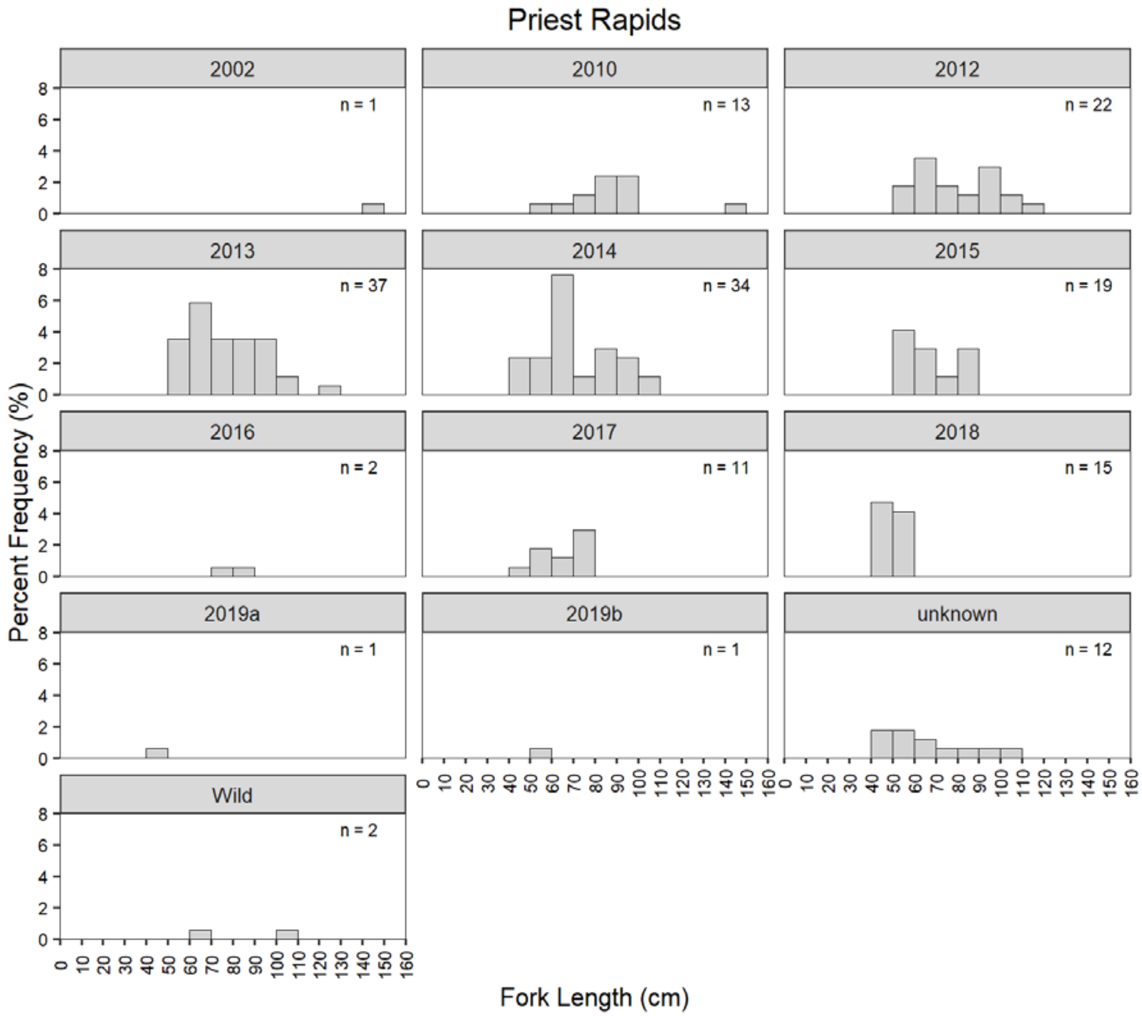

Figure 19 **Length-frequency distribution by brood year for hatchery White Sturgeon captured in Priest Rapids reservoir during the juvenile White Sturgeon indexing program, September 27 to October 23, 2021.**

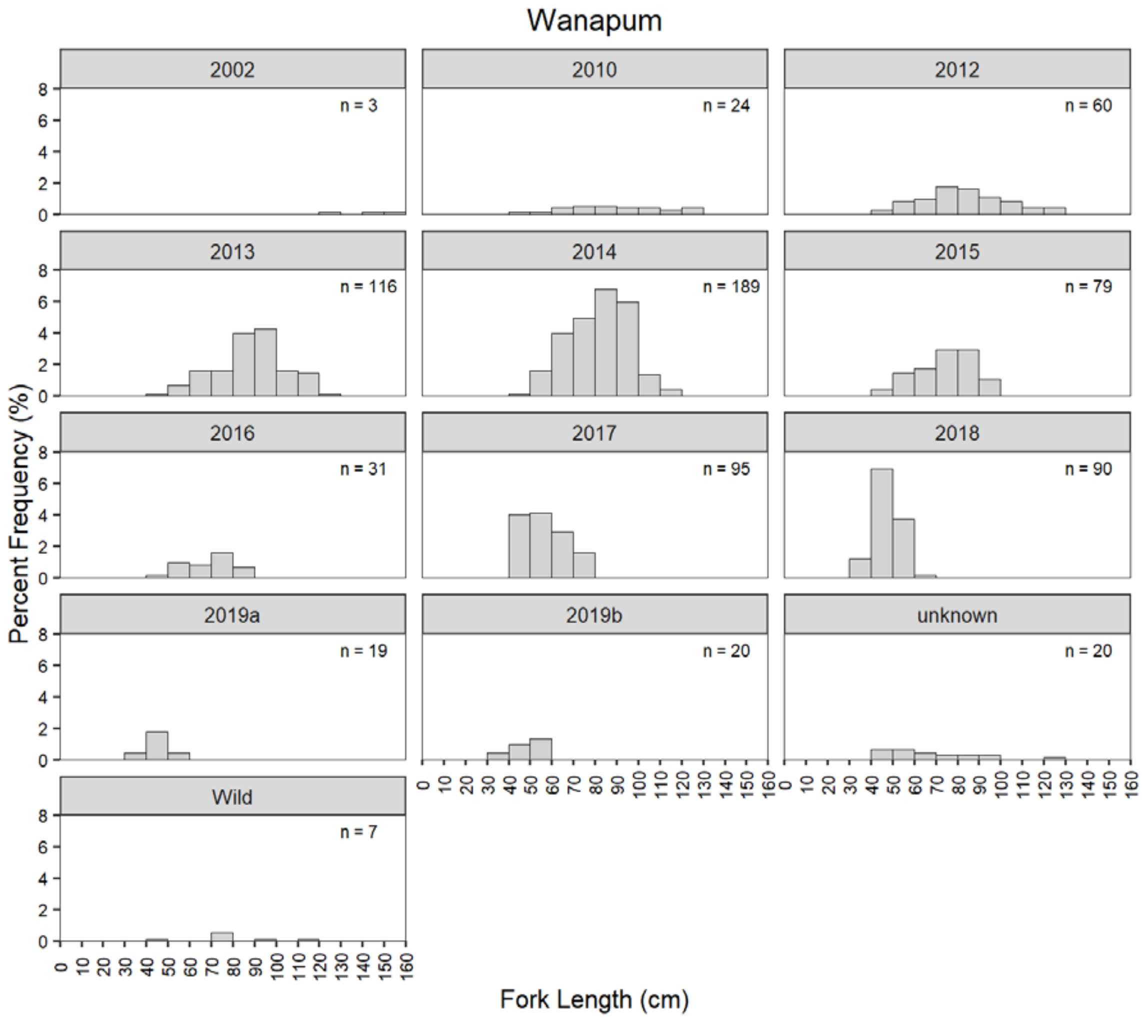

Figure 20 Length-frequency distribution by brood year for hatchery White Sturgeon captured in Wanapum reservoir during the juvenile White Sturgeon indexing program, September 27 to October 23, 2021.

Table 15 Fork length (cm) of White Sturgeon captured in Priest Rapids and Wanapum reservoirs during the juvenile White Sturgeon indexing program, September 27 to October 23, 2021. For individuals captured twice or more during the survey, the fork length recorded during first capture was used.

Program	Brood Year	Priest Rapid Fork Length (cm)					Wanapum Fork Length (cm)					Combined Fork Length (cm)				
		n	Mean	SD	Min	Max	n	Mean	SD	Min	Max	n	Mean	SD	Min	Max
CRITFC	2002	1	145.0	-	145.0	145.0	3	142.5	13.3	128.5	155.0	4	143.1	10.9	128.5	155.0
Chelan PUD	2010	1	86.0	-	86.0	86.0	-	-	-	-	-	1	86.0	-	86.0	86.0
	2012	-	-	-	-	-	1	106.5	-	106.5	106.5	1	106.5	-	106.5	106.5
	2014	-	-	-	-	-	4	74.6	17.6	52.0	93.0	4	74.6	17.6	52.0	93.0
	2015	-	-	-	-	-	1	85.0	-	85.0	85.0	1	85.0	-	85.0	85.0
	2018	-	-	-	-	-	1	40.5	-	40.5	40.5	1	40.5	-	40.5	40.5
Douglas PUD	2013	-	-	-	-	-	1	98.0	-	98	98	1	98.0	-	98	98
	2015	-	-	-	-	-	1	78.0	-	78	78	1	78.0	-	78	78
Grant PUD	2010	12	87.1	23.2	54.0	146.0	24	88.6	22.4	49.5	127.5	36	88.1	22.4	49.5	146.0
	2012	22	79.8	18.4	55.0	110.5	57	83.2	19.7	45.5	129.0	79	82.3	19.3	45.5	129.0
	2013	37	76.6	16.8	52.0	122.0	114	87.4	16.1	46.5	121.0	151	84.8	16.9	46.5	122.0
	2014	33	71.3	17.7	46.0	109.0	177	81.5	13.7	42.0	116.0	210	79.9	14.8	42.0	116.0
	2015	19	67.2	12.0	51.0	87.0	76	73.9	13.2	42.0	99.5	95	72.6	13.2	42.0	99.5
	2016	2	82.2	8.8	76.0	88.5	30	68.6	10.9	42.5	88.5	32	69.5	11.2	42.5	88.5
	2017	11	64.8	12.7	45.0	78.5	92	56.6	9.7	42.0	79.5	103	57.5	10.3	42.0	79.5
	2018	15	50.0	5.8	42.0	59.0	87	46.5	5.8	34.5	60.0	102	47.0	5.9	34.5	60.0
	2019a	1	44.0	-	44.0	44.0	19	44.7	4.1	37.0	52.5	20	44.7	4.0	37.0	52.5
	2019b	1	50.0	-	50.0	50.0	19	48.1	5.4	38.5	56.0	20	48.2	5.3	38.5	56.0
Unknown[1]	Unknown	12	65.5	21.0	45.0	109.5	20	66.2	20.6	43.5	120.0	32	66.0	20.4	43.5	120.0
Wild	Wild	2	82.5	24.7	65.0	100	6	80.0	21.5	47.5	111.0	8	80.6	20.5	47.5	111.0
All sturgeon	All	169	72.0	19.6	42.0	146.0	733	72.2	20.8	34.5	155.0	902	72.1	20.6	34.5	155.0

[1]Considered to be of hatchery origin based either on the presence of a PIT tag, marks, or substantial fin deformity, but brood year, source, or stocking location data are unknown.

Table 16 Weight (g) of White Sturgeon captured in Priest Rapids and Wanapum reservoirs during the juvenile White Sturgeon indexing program, September 27 to October 23, 2021.

Program	Brood Year	Priest Rapids					Wanapum					All				
		n	Mean	SD	Min	Max	n	Mean	SD	Min	Max	n	Mean	SD	Min	Max
CRITFC	2002	1	25,765	-	25,765	25,765	3	22,385	6,126	15,490	27,200	4	23,230	5,280	15,490	27,200
Chelan PUD	2010	1	5,155	-	5,155	5,155	-	-	-	-	-	1	5,155	-	5,155	5,155
	2012	-	-	-	-	-	1	7,595	-	7,595	7,595	1	7,595	-	7,595	7,595
	2014	-	-	-	-	-	4	3,674	2,150	1,010	6,000	4	3,674	2,150	1,010	6,000
	2015	-	-	-	-	-	1	4,835	-	4,835	4,835	1	4,835	-	4,835	4,835
	2018	-	-	-	-	-	1	645	-	645	645	1	645	-	645	645
Douglas PUD	2013	-	-	-	-	-	1	8,345	-	8,345	8,345	1	8,345	-	8,345	8,345
	2015	-	-	-	-	-	1	3,255	-	3,255	3,255	1	3,255	-	3,255	3,255
Grant PUD	2010	12	6,468	7,445	1,030	29,165	24	6,089	4,429	790	14,850	36	6,215	5,508	790	29,165
	2012	22	3,773	2,461	990	7,770	56	4,658	3,184	665	13,600	78	4,408	3,009	665	13,600
	2013	37	3,683	2,999	865	15,715	114	5,661	2,825	610	11,825	151	5,177	2,983	610	15,715
	2014	33	2,797	2,123	530	8,255	177	4,240	2,143	480	10,965	210	4,013	2,199	480	10,965
	2015	19	2,232	1,261	860	4,525	76	3,207	1,779	450	8,395	95	3,012	1,727	450	8,395
	2016	2	3,805	467	3,475	4,135	30	2,440	1,074	480	4,200	32	2,525	1,095	480	4,200
	2017	11	1,982	1,120	530	3,430	92	1,323	797	385	3,855	103	1,393	855	385	3,855
	2018	15	865	363	490	1,410	85	723	306	310	1,575	100	744	318	310	1,575
	2019a	1	610	-	610	610	19	521	162	305	830	20	526	159	305	830
	2019b	1	825	-	825	825	19	648	195	370	980	20	657	194	370	980
Unknown[1]	Unknown	12	2,342	2,500	535	7,965	20	2,762	3,029	530	12,215	32	2,605	2,808	530	12,215
Wild	Wild	2	4,998	4,126	2,080	7,915	6	4,573	3,689	710	10,930	8	4,679	3,492	710	10,930
All sturgeon	All	169	3,222	3,569	490	29,165	730	3,444	3,064	305	27,200	899	3,402	3,164	305	29,165

[1]Considered to be of hatchery origin based either on the presence of a PIT tag, marks, or substantial fin deformity, but brood year, source, or stocking location data are unknown..

3.5.4 Juvenile White Sturgeon Indexing Gear Performance

As noted in previous juvenile indexing studies, a portion of the small hook gangions used are damaged by large fish that either straighten hook or break the leader when they take the hook (Golder 2017). In 2021, the hooks on 268 gangions (33.5% of the Wanapum reservoir gear inventory) were damaged or lost in Wanapum reservoir, with slightly more 4/0 gangions damaged than 2/0 gangions (Table 17). Lost hooks, where the leader broke or the gangion detached from the set line, represented less than 2% (14 of 800 hooks) of the inventory. Damaged and lost hooks in relation to the number of hooks deployed in Wanapum reservoir over the study (10,799 gangions fished) was 2.5%.

Gear was damaged or lost in Priest Rapids reservoir at a lower rate than in Wanapum reservoir, with 53 of the 400 hooks (14.8%) damaged or lost. Approximately equal numbers of 2/0 and 4/0 hooks were damaged. Lost hooks represented 1.5% (6 of 400 hooks) of the gear allotment for Priest Rapids reservoir. Damaged and lost hooks in relation to the number of hooks deployed in Priest Rapids reservoir over the study (3,600 gangions fished) was 1.6%.

The 4/0 hook size caught 57% of the catch (430 of 753 fish) in Wanapum reservoir and 59% of the catch (100 of 170 fish) in Priest Rapids reservoir. The smallest fish caught by each hook size was similar. The largest fish caught by the 4/0 hooks was greater than the largest fish caught by 2/0 hooks. Mean catch of the 4/0 hooks was higher in each reservoir and they were marginally more effective in the capture of larger fish (Table 18).

Table 17 Hook rate and overall gangion damage and loss in the Priest Rapids Project area during the juvenile White Sturgeon indexing program in 2021.

Reservoir	Hook Size	Gangions		Hook/Gangion Fate				
		No. Set	Gear Inventory	Bent	Lost	Total	Proportion of Set Gangions with Damage or Lost Hooks	Proportion of Gangion Inventory with Damaged or Lost Hooks
		n	n	n	n	n	%	%
Wanapum	**2/0**	5,399	400	114	7	121	2.2	30.3
	4/0	5,400	400	140	7	147	2.7	36.8
Total		10,799	800	254	14	268	2.5	33.5
Priest Rapids	**2/0**	1,800	200	29	3	32	1.8	16.0
	4/0	1,800	200	24	3	27	1.5	13.5
Total		3,600	400	53	6	59	1.6	14.8
PRPA		14,399	1200	307	20	327	2.3	27.3

Table 18 White Sturgeon catch by hook size in the Priest Rapids Project Area during the juvenile White Sturgeon indexing program in 2021.

Reservoir	Hook Size	Catch	Fork Length (cm)			
		n	Mean	SD	Min	Max
Wanapum	2/0	323	68.3	19.8	34.5	129.0
	4/0	430	75.1	20.9	36.5	155.0
Priest Rapids	2/0	70	68.8	16.9	43.0	110.5
	4/0	100	74.2	20.9	42.0	146.0

3.5.5 Hatchery Juvenile White Sturgeon Abundance Estimates

Capture success during the 2021 juvenile White Sturgeon indexing program was sufficient to construct a set of Cormack-Jolly-Seber models to estimate survival and recapture probabilities of juvenile hatchery White Sturgeon in Priest Rapids and Wanapum reservoirs. Of the 6 models constructed, 4 converged and were used to calculate model-averaged values of recapture and survival estimates. Of these 4 models, the model with the lowest QAICc had survival as a multiplicative function between brood year and reservoir, with an additive effect of age class (i.e., first year after release or any subsequent year) and recapture probability as a multiplicative function of age (as a categorical variable) and release reservoir. The weighting for this model was 1.0, indicating no support for other models.

For all brood years, mean survival estimates were lower in the first-year post-release than in subsequent years at large (Figure 21). In Priest Rapids reservoir, survival in the first year post-release was highest for 2010BY (mean of 0.565, 95% CI = 0.459–0.667). The remaining brood years had similar survival in the first year post-release, with mean estimates ranging between 0.027 (2016BY) to 0.219 (2019BYa). In Wanapum reservoir, 2010BY had similar survival to most other brood years, while 2016BY had the lowest survival, similar to the 2016BY in Priest Rapids reservoir, with a mean of 0.081 (95% CI = 0.051–0.127). The survival in first year post-release for the remaining brood years ranged from 0.243 (2014BY) to 0.357 (2019BYa).

In subsequent years post-release, survival was generally high for both reservoirs, ranging between 0.787 (2016BY) and 0.994 (2010BY) in Priest Rapids reservoir, and between 0.922 (2016BY) and 0.989 (2017BY) in Wanapum reservoir. During the 2015/2016 period, when some of the 2010BY fish may have been culled or harvested in the Tribal and sport fisheries, survival was estimated to be particularly low in Priest Rapids reservoir, with a mean of 0.443 (95% CI = 0.325–0.569). In Wanapum reservoir, the 2010BY survival associated with the cull / fishery period was higher, with a mean of 0.786 (95% CI = 0.665–0.872).

Recapture probabilities generally decreased with fish age for the oldest brood years, and generally increased with age for the younger brood years (Figure 22). Overall, recapture probabilities in Wanapum reservoir were two to three times higher compared to fish of the same age in Priest Rapids reservoir.

The model-averaged survival estimates were used to calculate total annual population values with 95% confidence intervals to describe abundance of hatchery juvenile White Sturgeon released in the PRPA for each calendar year from 2011 to 2021 (Figure 23; Table 19). After the initial release of hatchery fish in 2011, the 2012 population abundance estimated for both reservoirs decreased, as hatchery fish were not released in 2012 (i.e., a 2011BY was not released). From 2012 to 2015, each successive annual release of hatchery fish was reflected in step increases in total annual population abundance estimates (Figure 23). From 2015 (for Priest Rapids reservoir) and 2016 (for Wanapum reservoir) to 2019, the estimated population abundance of hatchery White Sturgeon in each reservoir remained steady, followed by a decline between 2019 and 2020, when only 672 fish were released into the PRPA, which was not sufficient to compensate for the mortality of previously released fish. With the release of the 2019BYb, the 2021 hatchery fish abundance estimate in Wanapum reservoir was 8,292 fish (95% CI = 6,748–9,836) or 29.1% of total hatchery releases to date (n = 28,489 fish). In Priest Rapids reservoir, the 2021 hatchery fish abundance estimate was 2,408 fish (95% CI = 1,744–3,073) or 19.6% of total hatchery releases to date (n = 12,256 fish).

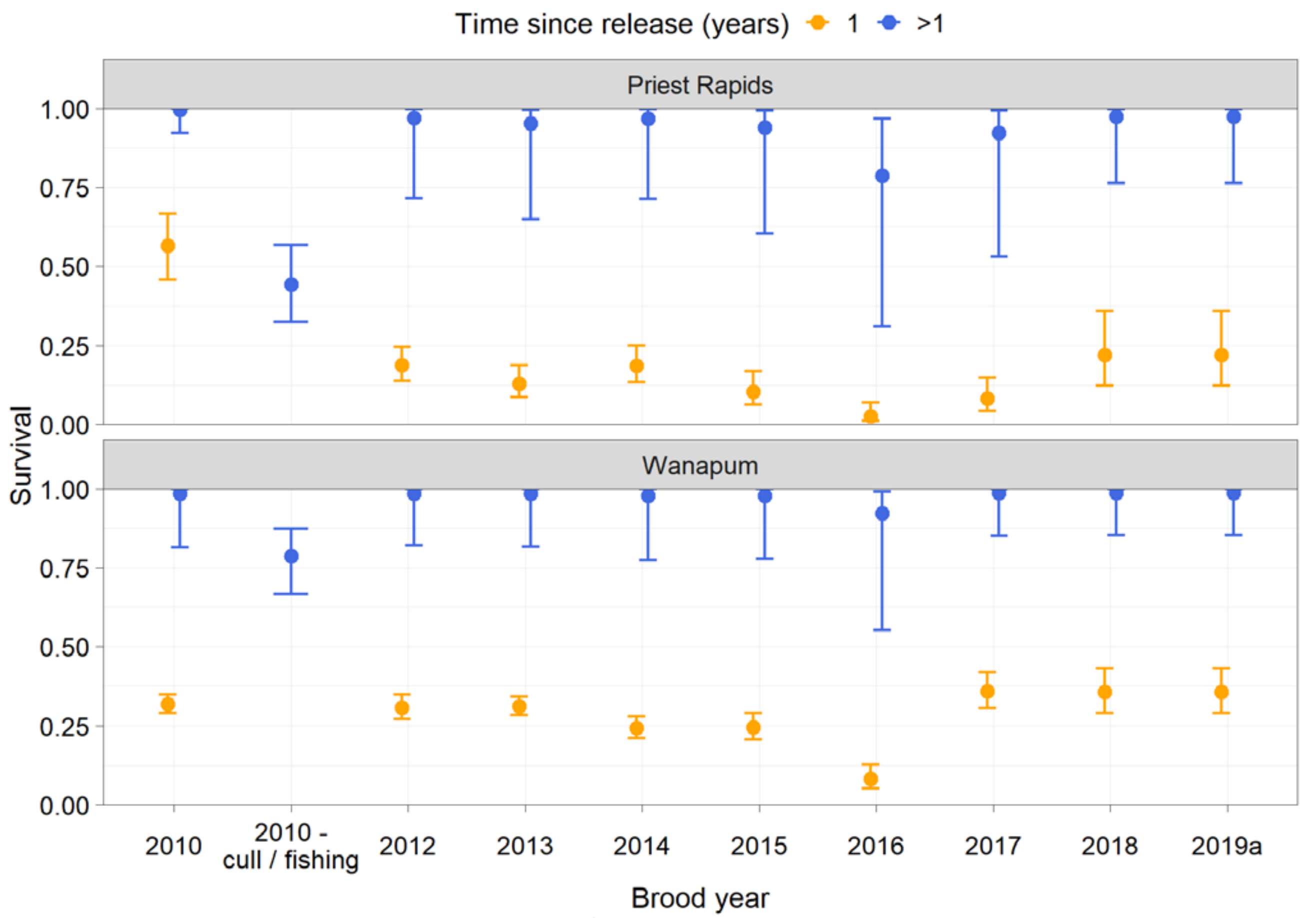

Figure 21 **Estimated survival of hatchery juvenile White Sturgeon by brood year, reservoir, and age class (i.e., first year post-release or in any subsequent year combined).**

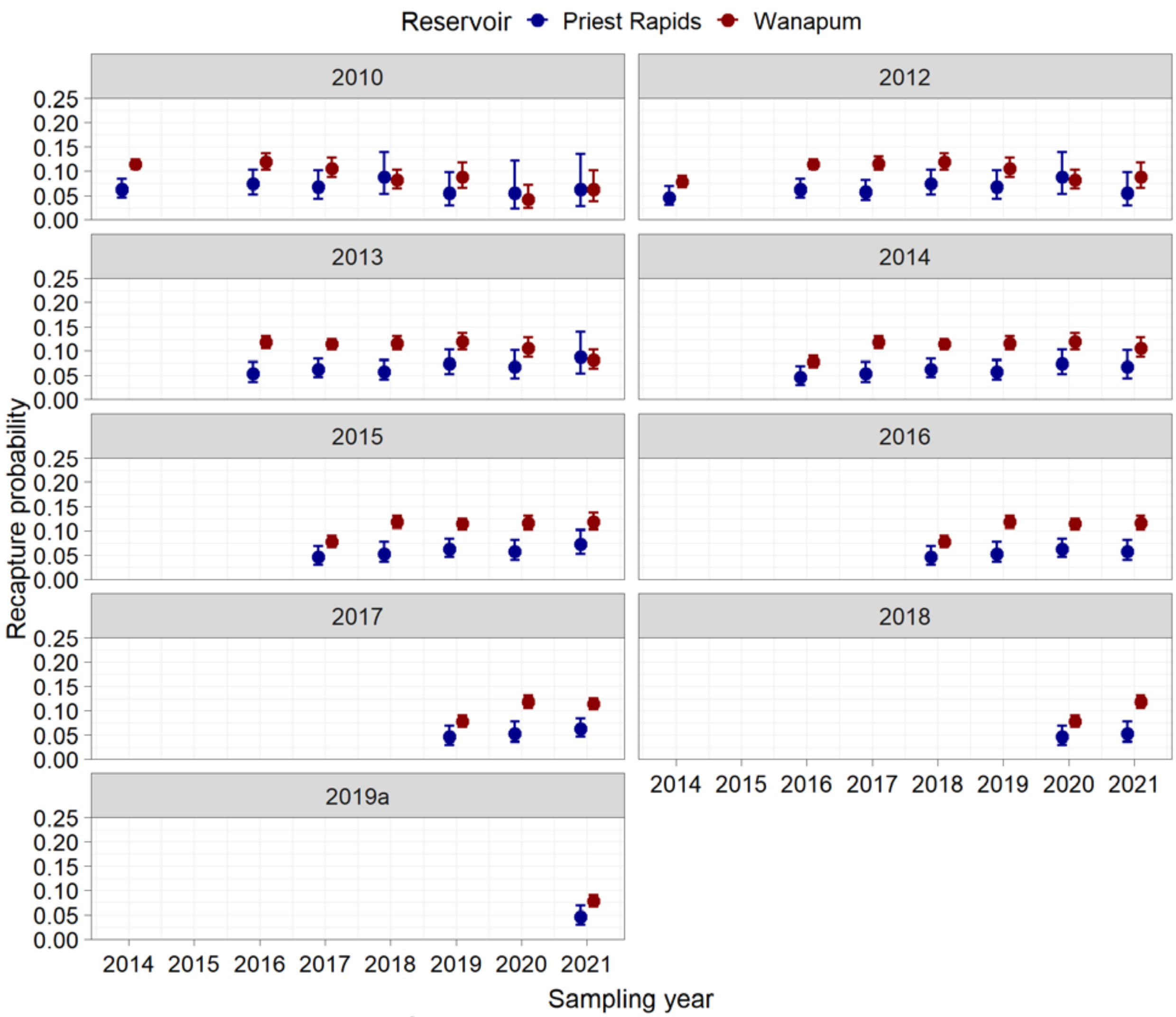

Figure 22 Estimated probability of recapture of hatchery juvenile White Sturgeon by age, brood year, and reservoir.

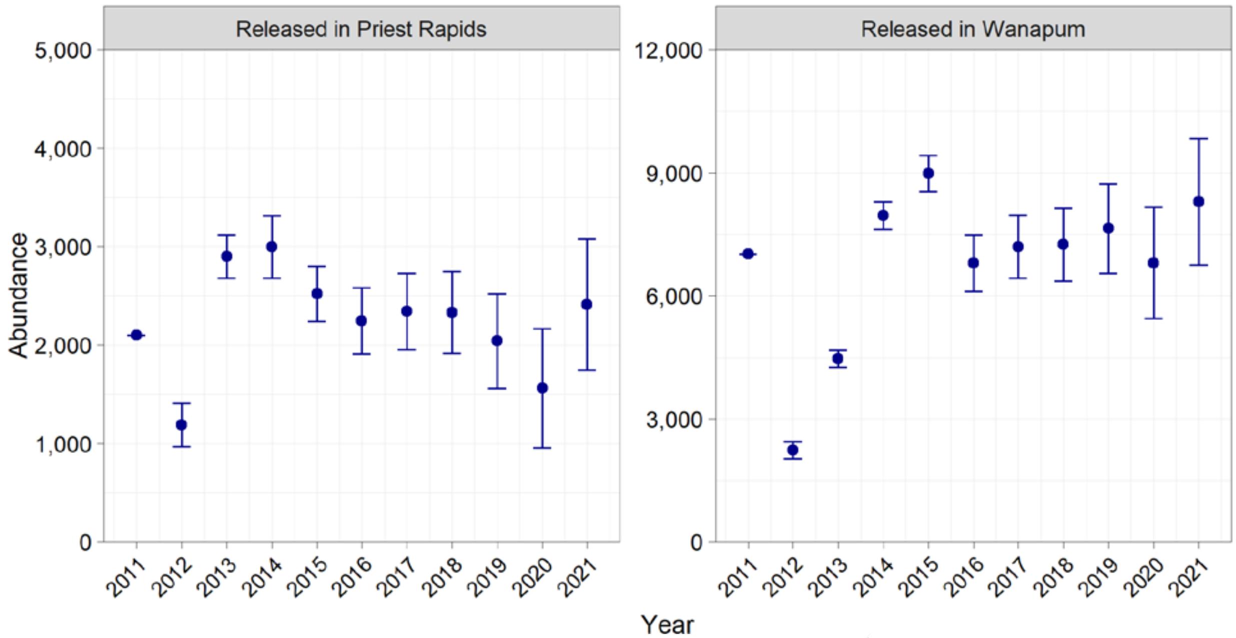

Figure 23 Estimated abundance of hatchery juvenile White Sturgeon (based on survival of 2010BY to 2019BYa releases) by calendar year for Wanapum and Priest Rapids reservoirs, 2011 to 2021.

Table 19 Estimated total abundance of the hatchery juvenile White Sturgeon (2010BY to 2019BYa) releases in the Priest Rapids Project area by calendar year and in relation to annual and cumulative hatchery releases, 2011 to 2021.

Pool	Year	Abundance Estimate (95% CI)	Annual Hatchery Release Number	Cumulative Release Number
Wanapum	2011	7,015 (7,015 – 7,015)	7,015	7,015
	2012	2,233 (2,028 – 2,437)	0	7,015
	2013	4,461 (4,252 – 4,671)	2,264	9,279
	2014	7,950 (7,613 – 8,288)	5,092	14,371
	2015	8,980 (8,533 – 9,427)	5,007	19,378
	2016	6,795 (6,109 – 7,481)	2,005	21,383
	2017	7,196 (6,429 – 7,964)	1,999	23,382
	2018	7,248 (6,359 – 8,137)	1,983	25,365
	2019	7,639 (6,549 – 8,730)	1,767	27,132
	2020	6,802 (5,452 – 8,152)	411	27,543
	2021	8,292 (6,748 – 9,836)	946	28,489
Priest Rapids	2011	2,101 (2,101 – 2,101)	2,101	2,101
	2012	1,188 (967 – 1,410)	0	2,101
	2013	2,899 (2,676 – 3,121)	1,717	3,818
	2014	2,995 (2,678 – 3,311)	1,500	5,319
	2015	2,519 (2,238 – 2,801)	1,495	6,814
	2016	2,244 (1,908 – 2,580)	1,253	8,067
	2017	2,342 (1,954 – 2,729)	1,249	9,316
	2018	2,332 (1,918 – 2,746)	1,241	10,566
	2019	2,042 (1,561 – 2,523)	890	11,446
	2020	1,562 (958 – 2,166)	261	11,707
	2021	2,408 (1,744 – 3,073)	549	12,256

3.6 Assessment 2010-2019BY Growth

Annual growth rate was calculated for each brood year released in the PRPA, based on the difference in fork length between release and capture, divided by the time at large for fish more than one year at large (Table 20). The catch results from the adult and juvenile indexing programs were combined and used to calculate growth rates for each brood year in each reservoir and each reservoir section. In general, growth rates of young fish were higher than older fish and gradually decrease as the fish age. Across all brood years, mean growth rates were generally highest in the lower sections of each reservoir, decreased in the middle sections, and were lowest in the upper sections of each reservoir (Figure 24). This declined in growth rate was most pronounced in young brood years (i.e., 2017BY, 2018BY) and was also evident in the older brood years (i.e., 2013BY and 2014BY) that were captured in substantial numbers in all reservoir sections.

Table 20 Growth of the 2010BY to 2019BYa by reservoir section in PRPA during adult and juvenile White Sturgeon indexing, 2021

Brood Year	Priest Rapids Lower Section Growth (cm FL/year)					Priest Rapids Middle Section Growth (cm FL/year)					Priest Rapids Upper Section Growth (cm FL/year)				
	n	**Mean**	**SD**	**Min**	**Max**	**n**	**Mean**	**SD**	**Min**	**Max**	**n**	**Mean**	**SD**	**Min**	**Max**
2010	2	**8.6**	2.8	6.6	10.6	3	**7.9**	4.2	5.0	12.7	12	**5.8**	2.3	2.2	9.9
2012	4	**9.2**	2.0	7.7	11.9	8	**6.4**	1.8	4.0	8.4	21	**5.1**	1.9	2.9	9.3
2013	23	**9.9**	2.3	4.8	13.6	15	**7.0**	2.0	4.1	11.5	30	**5.2**	1.6	2.4	8.9
2014	15	**8.8**	2.2	5.8	12.6	11	**4.6**	1.4	1.9	6.7	27	**5.5**	2.4	1.4	9.3
2015	11	**8.7**	1.4	5.9	10.2	9	**5.5**	0.8	4.0	6.9	12	**5.1**	1.7	2.8	8.6
2016	3	**12.2**	0.9	11.2	12.8	-	-	-	-	-	-	-	-	-	-
2017	10	**13.4**	1.8	9.7	15.8	4	**7.7**	2.0	6.3	10.6	4	**8.3**	3.4	6.2	13.3
2018	11	**12.7**	1.5	10.7	15.1	8	**8.8**	2.0	5.6	12.1	5	**8.2**	2.2	5.8	10.5
2019a	1	**18**	-	18.0	18.0	-	-	-	-	-	-	-	-	-	-
Brood Year	**Wanapum Lower Section Growth (cm FL/year)**					**Wanapum Middle Section Growth (cm FL/year)**					**Wanapum Upper Section Growth (cm FL/year)**				
	n	**Mean**	**SD**	**Min**	**Max**	**n**	**Mean**	**SD**	**Min**	**Max**	**n**	**Mean**	**SD**	**Min**	**Max**
2010	3	**7.9**	1.2	6.7	9.2	4	**8.2**	1.9	6.0	9.8	26	**5.8**	2.1	1.8	9.8
2012	6	**9.8**	1.7	7.5	11.9	28	**7.7**	2.1	4.3	11.1	64	**5.6**	2.2	1.7	11.3
2013	59	**9.6**	1.6	6.6	12.3	71	**8.5**	1.7	4.4	12.1	72	**6.7**	2.2	2.6	12.7
2014	70	**9.4**	1.5	5.2	12.9	77	**7.8**	1.6	5	11.4	93	**6.7**	2.2	1.3	11.3
2015	24	**10.4**	1.5	6.6	12.8	33	**8.6**	2.0	4.2	12.4	49	**6.7**	2.4	1.7	12.5
2016	11	**11.3**	0.9	9.9	13.1	15	**9.4**	2.0	5.9	12.3	12	**7.7**	2.8	3.6	13.0
2017	28	**11.9**	2.6	7.0	19.8	54	**8.4**	2.3	3	12.6	46	**6.3**	2.3	2.4	11.4
2018	8	**11.8**	1.2	9.9	13.4	41	**9.5**	2.1	4.7	13.4	47	**6.4**	1.8	3.2	10.8
2019a	3	**14.3**	5.5	10.5	20.6	10	**6.2**	4.7	1.7	15.6	7	**4.0**	2.5	0.7	7.4

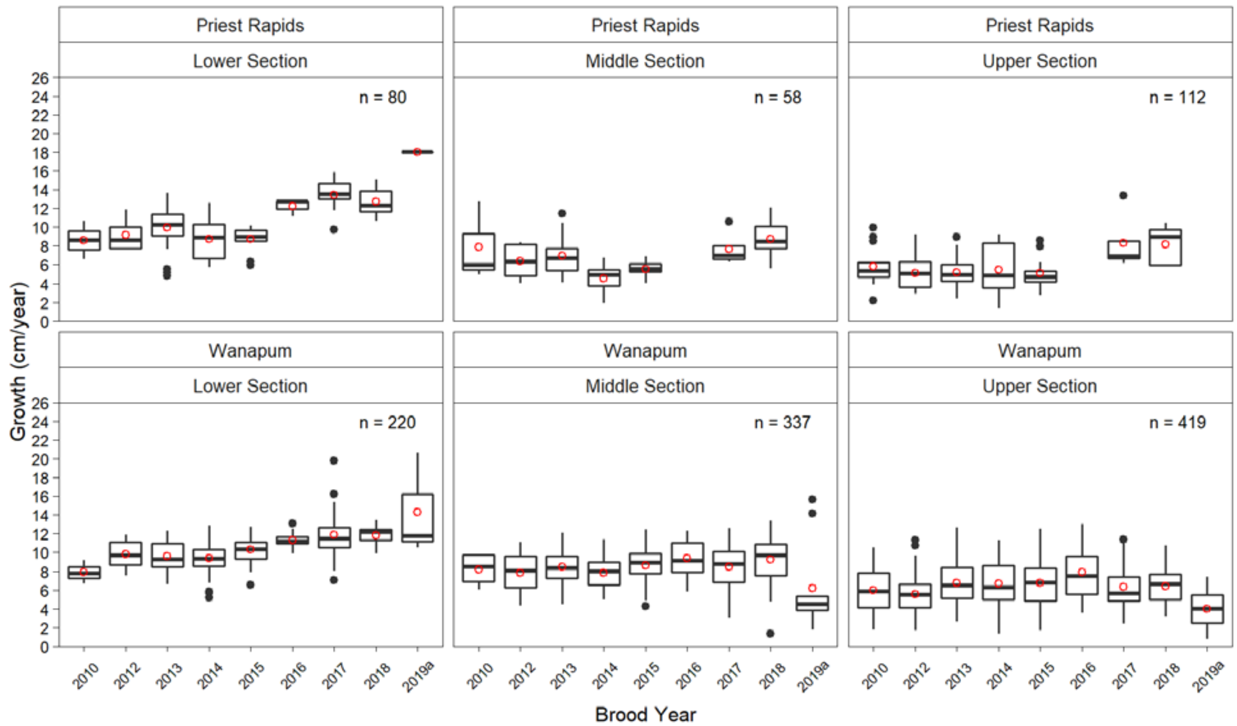

Figure 24 Growth rates of brood years 2010 through 2019a (fish one year or more years at large) captured during adult and juvenile indexing in the lower, middle, and upper sections of Priest Rapids and Wanapum reservoirs, 2021. Red circles represent mean growth.

For the combined adult and juvenile indexing catch, difference in brood year growth rates by reservoir and reservoir section was reflected in the relative weight calculations for each brood year and in relation to reservoir section where most of the fish were captured (Figure 25). In Wanapum reservoir, based on the condition factor calculated for each fish, a greater proportion of the 2013BY and 2018BY had lower relative weights in relation to the mean relative weight, with the distribution of relative weights of other brood years either distributed uniformly or slightly above the mean (i.e., 2017BY). A similar trend was also evident in Priest Rapids reservoir in that the relative weight of 2018BY was below average in relation to other brood years. Based on combined adult and juvenile indexing catch, relationships between log^{10} FL and log^{10} weight were highly significant and regression slope parameter estimates for Wanapum reservoir (slope = 3.2) were slightly higher than estimates for Priest Rapids reservoir (slope = 3.1; Figure 26) and suggests slightly higher growth rates in Wanapum reservoir than in Priest Rapids reservoir.

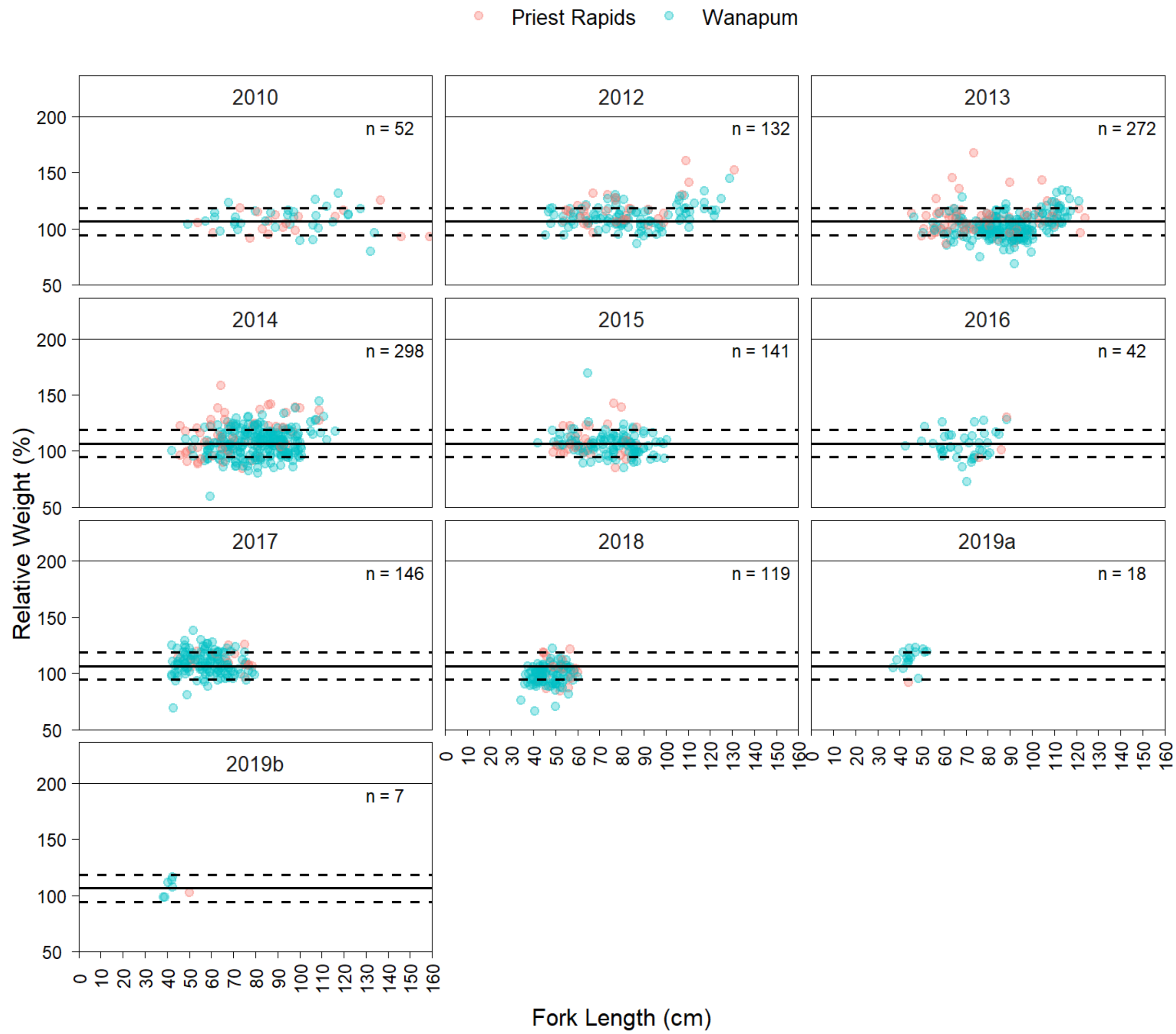

Figure 25 **Relative weight in relation to fork length for each brood year of hatchery juvenile White Sturgeon captured in Wanapum and Priest Rapids reservoirs during the adult and juvenile White Sturgeon indexing programs, August 16 to October 23, 2021.**

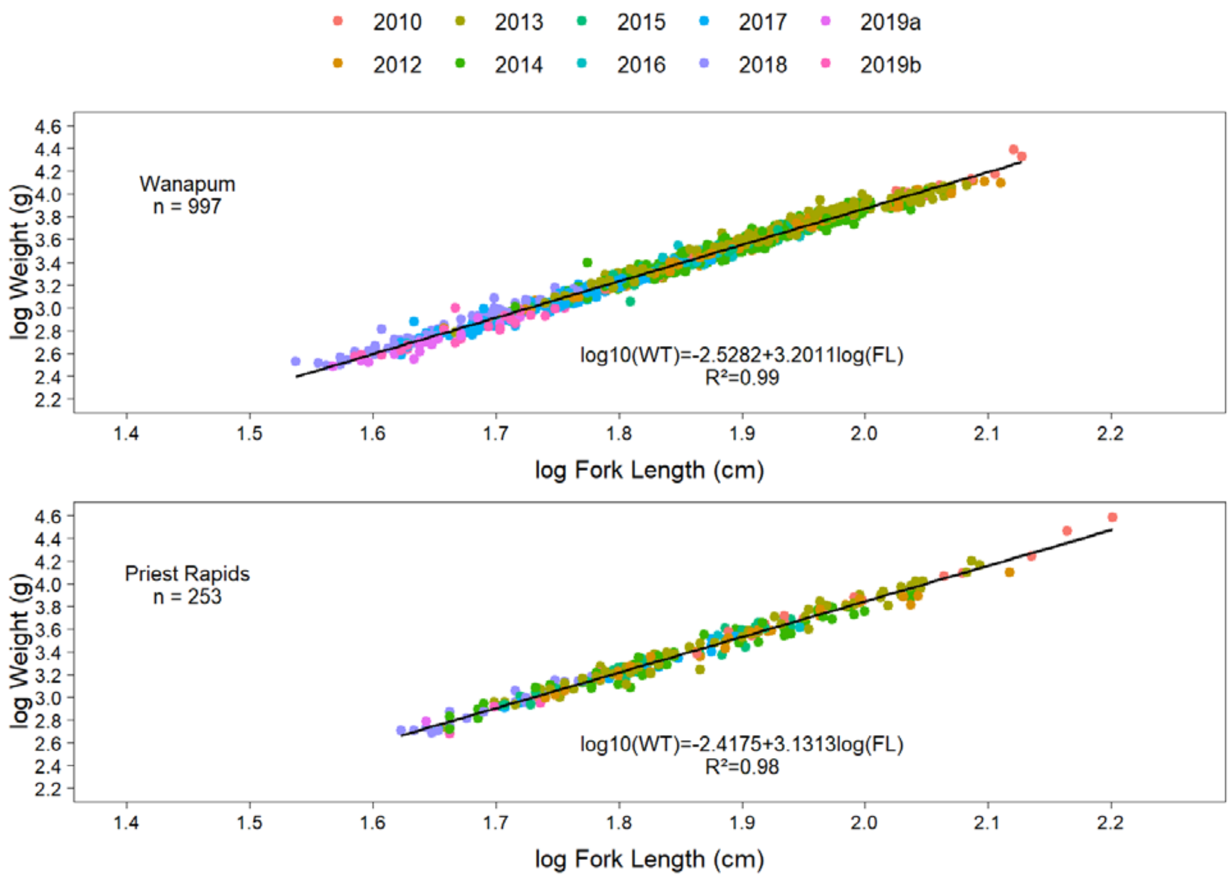

Figure 26 Linear regression of log10 fork length and log10 weight for hatchery juvenile White Sturgeon of each brood year captured in Wanapum and Priest Rapids reservoirs during the adult and juvenile White Sturgeon indexing program, August 16 to October 23, 2021.

3.6.1 Assessment of Density Dependent Growth

Fish growth varied with both brood year and reservoir (Figure 27). The combined PRPA population of hatchery-reared sturgeon did not exhibit clear signs of density-dependent growth. While the 2010BY generally had the highest growth of the early brood years, and while the 2012BY had depressed growth in comparison, later brood years (2013BY, 2014BY, and 2015BY) had growth rates that fell between those of 2010BY and 2012BY, and were nearly identical. This suggests no overall decreasing trend in growth as more fish are released in the PRPA. The later brood years analyzed (2016BY and 2017BY) appear to have growth rates similar to 2015BY.

Growth differed for fish in Wanapum reservoir and fish in Priest Rapids reservoir. Fish in Priest Rapids reservoir exhibited plateaued growth earlier (e.g., 2010BY growth slowed down by age-6 in Priest Rapids reservoir but did not slowdown in Wanapum reservoir). In Priest Rapids reservoir, 2010BY also had a high growth rate, followed by 2013BY and 2015BY. In comparison, 2014BY had the lowest growth rate, estimated to reach only 62 cm by age-6, whereas 2010BY were estimated to reach 76 cm by the same age. While the curve for 2016BY was estimated to be similar to that of 2010BY, it was influenced by a single 2016BY fish caught at age-5. More recaptures are required to better evaluate the growth rate of this brood year.

Overall, in Priest Rapids reservoir, differences in growth were observed between brood years, and it is not currently understood whether density-dependent growth reduction is occurring. Once growth of the younger brood years (2016BY-2019BY) can be assessed, it may become clearer whether the slow growth of 2014BY is also observed in the younger brood years or whether it was a single brood year affected by factors other than juvenile sturgeon densities.

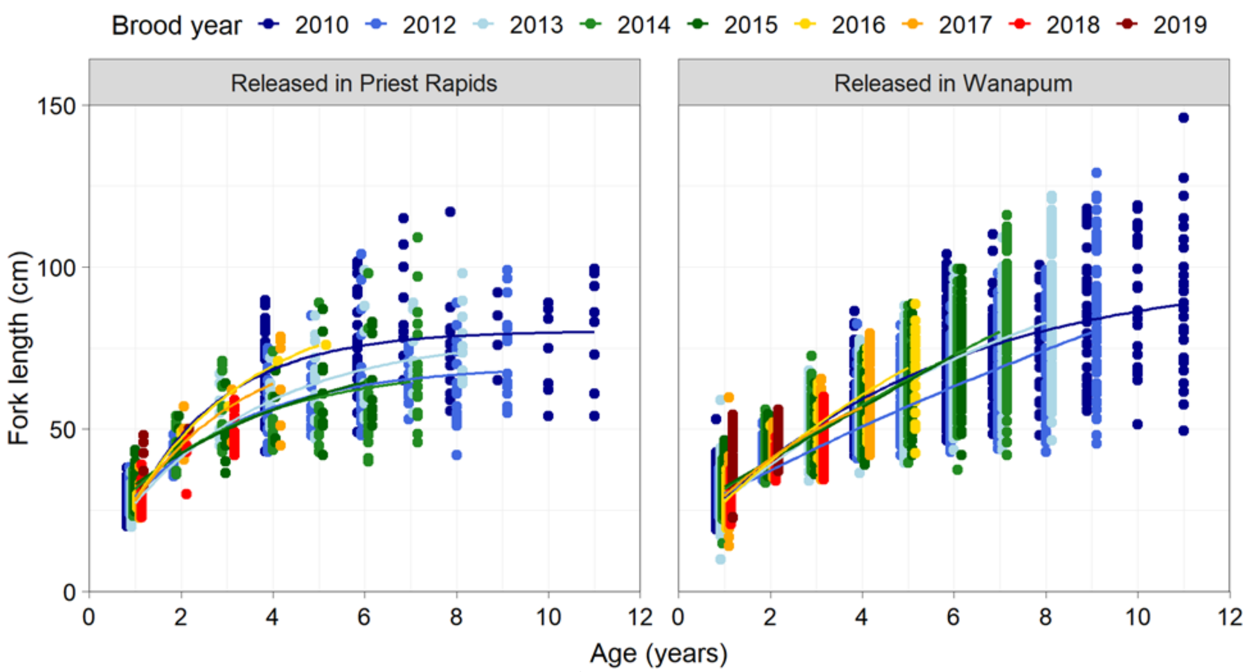

Figure 27 Estimated growth of hatchery juvenile White Sturgeon by brood year, within each release reservoir.

4.0 Discussion

The following sections provide a discussion of the 2021 (FERC License Year 14) M&E program results for the PRPA in context with previous study results. In 2021, activities included the tagging and release of all 2019BY juvenile White Sturgeon remaining at the YNSH (i.e., 2019BYb), adult White Sturgeon population indexing, and juvenile White Sturgeon population indexing.

4.1 Discharge and Temperature

A peak discharge volume of 19,675 kilo-acre feet (KAF) in 2021 was approximately equal to the annual average peak discharge volume of 19,877 KAF in the Project area from 2010 to 2020 (Figure 28). The 2021 peak flows occurred slightly later than the peak of the historical average discharge and freshet flows declined sharply in August and into September compared to previous flow years. During the three adult indexing studies conducted in 2015, 2018, and 2021, the 2021 peak freshet discharge volume exceeded peak discharge volume in 2015 (13,657 KAF), but was substantially lower than the 2018 peak discharge volume (32,790 KAF). Total annual 2021 discharge volume (78,770 KAF) was below the 2010-2020 average (89,315 KAF). The combination of low flow and very warm weather in summer 2021 resulted in above average water temperatures from August to September during adult White Sturgeon population indexing (Figure 29). The flow and water temperature regime during juvenile indexing in late September and October were consistent with the 2010-2020 average and likely did not have a substantial effect on the study results.

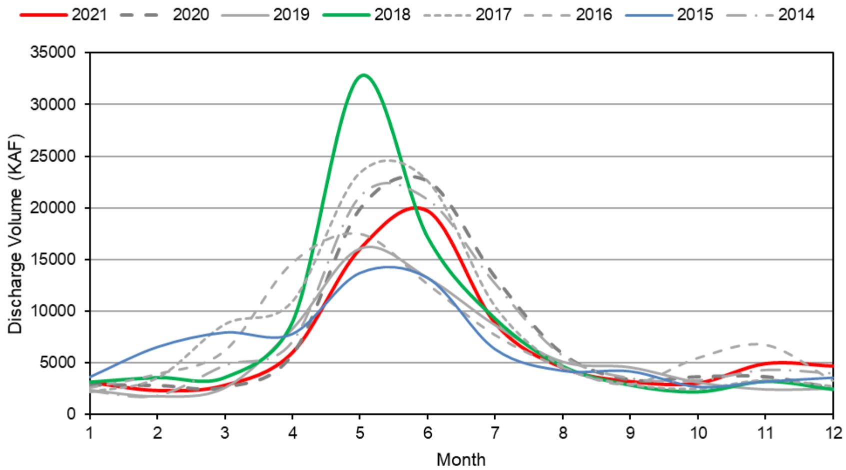

Figure 28 **The 2021 mean monthly discharge volume (red line) in comparison with the mean monthly discharge volume in the Project area from 2014 to 2020, as recorded at Rock Island Dam. Colored solid lines indicate years when adult White Sturgeon indexing was conducted.**

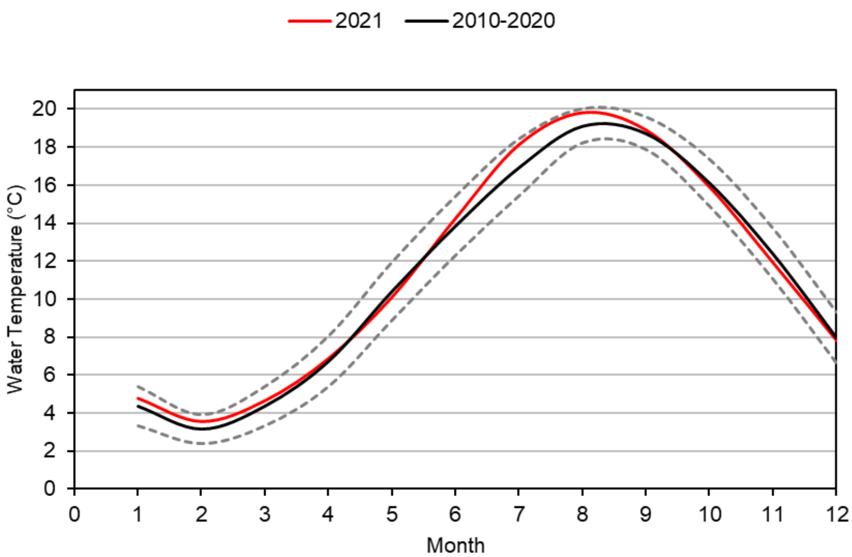

Figure 29 **The 2021 mean monthly water temperature (red line) in comparison with the 2010 to 2020 mean monthly water temperature (black line) and standard deviation (dashed line) of in the Project area as recorded at Rock Island Dam.**

4.2 Juvenile White Sturgeon Processing and Release (2019BYb)

Spawned on June 14, 2019, the 2019BY hatchery release were released as two separate groups, designated the 2019BYa (released in 2020) and 2019BYb (released in 2021). The 2019BYa release consisted of 672 fish, while the 2019BYb release consisted of 1485 fish. The 2019BYb were held and reared for approximately 22 months at YNSH and are the oldest and largest juvenile hatchery White Sturgeon released in the PRPA to date. Testing of individuals from 2019BYb for spontaneous autopolyploidy prior to tagging was included as part of the juvenile White Sturgeon tagging procedures in 2021. Preliminary testing in 2019 determined that between 2% and 4% of the 1500 remaining 2019BY were likely positive for spontaneous autopolyploidy (personal communication, Chris Mott, Grant PUD, October 8, 2019). As such, approximately 30 to 60 fish were expected to have spontaneous autopolyploidy. In 2021, testing identified 16 fish with spontaneous autopolyploidy out of the 1500 fish processed. The additional time required to test each fish for spontaneous autopolyploidy limited the number of fish processed and tagged per day to between 500 to 600 fish, a reduction from approximately 1,000 fish per day during previous tagging years. However, field crews noted that the large size of the nearly age-2 2019BYb also contributed to the reduced tagging rate. Even though future releases will likely consist of smaller age-1 fish, additional time requirements for spontaneous autopolyploidy testing should be accounted for when planning future tagging efforts. With the 2019BYb release in 2021, a total of 40,735 hatchery juvenile White Sturgeon have been released in the PRPA to date (Table 21).

The length and weight of fish at the time of their release may be variables that influences post-release survival, in that smaller fish may experience higher rates of predation and higher post-release mortality than larger fish (Justice et al. 2009). Given the larger size (mean = 483 mm FL) and weight (mean = 783 g) of the 2019BYb at release, a higher survival rate would be expected. During adult and juvenile White Sturgeon indexing in 2021, low numbers of both 2019BYa and 2019BYb were captured. Although both the same age, the 2019BYa fish captured were approximately 80 to 100 mm smaller than the 2019BYb fish captured. These data indicate that the 2019BYb, which were held at the hatchery for an additional year, grew more over the same time period than the 2019BYa that were released in the Project area the previous year. This finding, although not entirely unexpected, is an example of the difference in growing conditions between the hatchery environment and the release reservoir and the change in growth fish experience when released into a new environment.

The 2019BYb were also the first brood year of hatchery fish to be released at the new release locations in Priest Rapids reservoir, at the Priest Rapids Recreation Area boat launch (RM400.3), and in Wanapum reservoir, at the Vantage boat launch (RM420.6). Dispersal of these juvenile fish from the release sites was confirmed during the adult White Sturgeon indexing study, with capture of 2019BYb in the upper section of Priest Rapids reservoir, and during the juvenile indexing study, with the capture of 2019BYb fish in the upper section of Wanapum reservoir.

During tagging of the 2019BYa in 2020, fin deformities were observed and recorded in 97% of fish (654 of 672 fish). A similar rate of fin deformity was also recorded for the 2019BYb in 2021. This fin deformity rate was substantially higher than the 2018BY (31%) released in 2019. Even though some proportion of each annual hatchery juvenile sturgeon release have had fin deformities, the cause of the high level recorded in the 2019BY was unknown. As discussed in previous reports, the long-term biological implications of fin deformities on White Sturgeon survival, growth, and future reproductive success are not known (Golder 2018). However, during population indexing studies, fish with and without fin deformities from each hatchery brood year release have been captured in proportions that approximately equaled fin deformity rates reported for those brood years at release (Golder 2018). These capture data suggest that fin deformities do not appear to have a substantial effect on the survival of White Sturgeon during their early life history. During earlier years of the adult White Sturgeon population indexing and broodstock capture studies in the PRPA (Golder 2015), low numbers of adult fish with deformed or missing fins were captured. These fish appeared healthy and had mature or maturing gonads.

Table 21 Summary by brood year of hatchery White Sturgeon juveniles released in the Project area.

Brood Year	Reservoir	Release Location	River Mile	Brood Source	Release Date	Number Released[4]	Fork Length (cm) Mean	Fork Length (cm) SD	Weight (g) Mean	Weight (g) SD
2010	Wanapum	Columbia Siding	450.6	UCW[1]	26-Apr-11	2,019 (20)	24.6	3.0	174	97
				MCW[2]	29-Apr-11	2,996 (30)	28.8	3.6		
				LCC[3]	27-29 Apr 2011	2,000 (20)	34.7	3.6		
				All	--	7,015 (70)	29.3	5.1		
	Priest Rapids	Wanapum Dam Tailrace	415.6	UCW	26-Apr-11	900 (9)	24.8	2.8	187	105
				MCW	28-Apr-11	601 (6)	29	3.6		
				LCC	28-Apr-11	600 (6)	35.9	2.9		
				All	--	2,101 (21)	29.8	5.3		
				Total 2010		**9,116 (91)**	**29.4**	**5.2**	**177**	**99**
2012	Wanapum	Columbia Siding	450.6	MCW	14-May-13	1,135 (13)	29.2	2.7	156	45
		Columbia Cliffs	442	MCW	14-May-13	1,129 (11)	29.8	2.6		
		All	--	MCW	--	2,264 (24)	29.5	2.6		
	Priest Rapids	Wanapum Dam Tailrace	415.6	MCW	14-15 May 2013	1,717 (6)	28.5	2.4	149	41
				Total 2012		**3,981 (30)**	**29.1**	**2.6**	**154**	**44**
2013	Wanapum	Rocky Coulee	421.5	MCW	6-May-14	3,330 (32)	26.6	4.0	118	52
				MCW	18-Sep-14	1,762 (20)	29.1	4.4	152	74
				All	--	5,092 (52)	27.5	4.3	129	63
	Priest Rapids	Wanapum tailrace	415.6	MCW	5-May-14	996 (9)	27.2	4.2	131	56
				MCW	17-Sep-14	504 (5)	28.1	4.3	135	73
				All	--	1,500 (14)	27.5	4.2	133	63
				Total 2013		**6,592 (66)**	**27.5**	**4.3**	**130**	**63**
2014	Wanapum	Frenchman Coulee	424.5	MCW	30-Apr to 1-May 2015	5,007 (48)	31.3	2.9	199	55
	Priest Rapids	Wanapum Dam Tailrace	415.6	MCW	30-Apr to 1-May 2015	1,495 (15)	31.5	3.5	194	57
				Total 2014		**6,502 (63)**	**31.3**	**3.0**	**198**	**56**
2015	Wanapum	Frenchman Coulee	424.5	MCW	28-Apr-16	2,005 (25)	30.4	2.7	173	47
	Priest Rapids	Wanapum Dam Tailrace	415.6	MCW	28-Apr-16	1,253 (7)	30.1	2.6	167	44
				Total 2015		**3,258 (32)**	**30.3**	**2.6**	**171**	**46**
2016	Wanapum	Frenchman Coulee	424.5	MCW	2-May-17	1,999 (20)	27.0	3.2	125	47
	Priest Rapids	Wanapum Dam Tailrace	415.6	MCW	2-May-17	1,249 (12)	27.5	2.9	129	43
				Total 2016		**3,248 (32)**	**27.2**	**3.1**	**126**	**45**
2017	Wanapum	Frenchman Coulee	424.5	MCW	1-May-18	1,983 (20)	28.9	4.3	150	56
	Priest Rapids	Wanapum Dam Tailrace	415.6	MCW	1-May-18	1,241 (12)	27.9	4.1	136	59
				Total 2017		**3,224 (32)**	**28.5**	**4.3**	**144**	**58**
2018	Wanapum	Frenchman Coulee	424.5	MCW	7-May-19	1,767(0)	26.9	3.0	130	44
	Priest Rapids	Wanapum Dam Tailrace	415.6	MCW	7-May-19	890 (0)	26.5	2.8	124	40
				Total 2018		**2,657 (0)**	**26.7**	**2.9**	**128**	**43**
2019a	Wanapum	Frenchman Coulee	424.5	MCW	23-Jul-20	411 (0)	35.8	5.3	292	107
	Priest Rapids	Wanapum Dam Tailrace	415.6	MCW	23-Jul-20	261 (0)	35.1	5.0	282	104
				Total 2019a		**672 (0)**	**35.5**	**5.2**	**288**	**106**
2019b	Wanapum	Vantage	420.6	MCW	20-Apr-21	936 (0)	48.3	5.1	776	257
	Priest Rapids	Desert Aire	400.3	MCW	20-Apr-21	549 (0)	48.2	5.3	795	277
				Total 2019b		**1,485 (0)**	48.3	5.2	783	265
				Total 2010-2019		**40,735 (346)**	**30.4**	**3.7**	**205**	**74**

[1]Upper Columbia Wild (UCW) - the progeny of wild broodstock captured in the upper Columbia River in Canada and reared by the Freshwater Fisheries Society at Kootenay Sturgeon Hatchery in British Columbia
[2]Mid Columbia Wild (MCW) - the progeny of wild broodstock captured either in PRPA or below McNary Dam and reared at the Yakama Nation Sturgeon Hatchery (YNSH)
[3]Lower Columbia Cultured (LCC) - the progeny of captive broodstock originally captured below Bonneville Dam in the lower Columbia River.
[4]In years applicable, brackets indicated the number of fish in a release group that were implanted with acoustic tags.

4.3 Adult White Sturgeon Indexing

In 2003, approximately 20,600 hatchery juvenile White Sturgeon were released into Rock Island reservoir by the Columbia River Inter-Tribal Fish Commission (CRITFC). These fish were the brood produced from one female and two males (1Fx2M) spawned in 2002 (2002BY). A substantial proportion of the 2002BY fish either moved downstream or were entrained through Rock Island Dam and into Wanapum and Priest Rapids reservoirs. Large numbers of the 2002BY survived and these fish dominated the catch during indexing studies conducted in 2010 (Golder 2011), 2012 (Golder 2013), and 2015 (Golder 2016) and were commonly captured during broodstock collection efforts conducted from 2010 to 2014 in the PRPA. Due to the apparent high survival and limited genetic diversity of the 2002BY, a decision was made by the PRFF in 2015 to attempt to remove as many 2002BY fish from the PRPA as possible (Directions to Fish Forums from Policy Representatives, December 17, 2015). The rationale for the removal effort included concerns that a large breeding population of 2002BY could result in genetic swamping of the wild population and negatively affect future natural recruitment. Further rationale for the removal effort included providing an opportunity for the Yakama Nation to conduct a food fishery harvest and an opportunity for recreational sturgeon angling.

Capture efforts to remove the 2002BY from the PRPA were conducted from 2015 to 2018. Due to inconsistent scute marking of the 2002BY, the criterion for harvest was based on a size slot limit that allowed the retention of sturgeon between 96.5 cm and 183.0 cm fork length. The removal was conducted by Grant PUD biologists and contractors, Yakama Nation fisheries personnel, and guided and unguided public anglers. The removal methods used consisted of a combination of baited set lines and angling. Set line removal efforts by Yakama Nation peaked in 2016, with less effort applied in 2017 and 2018. Removal efforts were also conducted by guide assisted angling harvest over the same time period (Golder 2019). As explained in detail in the following sections, the final outcome of the removal efforts was considered mixed in that the population of 2002BY fish was reduced, but also inadvertently resulted in the loss of wild fish, and to a lesser extent the 2010BY fish, based on the 2018 and 2021 adult indexing catch compared to the 2015 adult indexing catch.

Adult Capture Effort and Catch

Capture effort and the sampling design in 2021 was consistent with the 2018 study, with equal effort in each reservoir section, whereas during the 2015 adult indexing study, the same level of effort was applied, but sample sites were distributed based on different site boundary criteria (Golder 2016). Mean total river discharge during the capture (mean = 2,857 m^3/s) and recapture (mean = 1572 m^3/s) sessions differed substantially in 2021, but did not seem to affect catch results, with 230 fish caught during the capture session and 213 fish caught during the recapture session. In total, 443 fish were captured and was more than the number captured in 2018 (n = 236), which was a high flow year compared to 2021 (see Figure 28). The following sections are a high-level review of the current and historic adult indexing data as it pertains to the 2002BY and wild fish, and the recently released 2010BY to 2019BY hatchery fish.

2002BY

In both 2018 and 2021, the 2002BY catch in Wanapum reservoir during the adult indexing program was approximately 6% of the 2015 catch (i.e., 17 fish in 2018 and 16 fish in 2021 vs 291 fish in 2015; Table 22). Similarly, the 2002BY catch in Priest Rapids reservoir in 2018 and

2021 was approximately 4% of the 2015 catch (i.e., 4 fish in both 2018 and 2021 vs 98 fish in 2015). The reduction in total catch of 2002BY in 2018 and 2021 compared to the 2015 catch was attributed to the removal efforts. Since the first adult indexing study in 2010, the average fork lengths of 2002BY fish caught in subsequent indexing studies were incrementally larger in each study year, with the 2021 catch approximately 50% longer than the 2010 catch. Based on bioassessment data, the 2002BY were robust and healthy and without notable fin deformities. At age-19, the 2002BY are considered mature adult fish capable of spawning. Surgical inspections conducted on 12 of the 20 2002BY captured in 2021 identified three mature females, with black eggs approximately 2.5 mm in diameter. Five males with white mature gonads were also identified. Two of these mature fish, one male and one female, were small enough to be considered as subadult based on the 150 cm FL delineator used to classify subadult and adult fish. As such, in the absence of surgical inspection and known age, these fish would not have been considered as potentially ripe fish ready to spawn based on size alone.

Table 22 Catch and fork length data for the 2002BY captured in the Priest Rapids Project area during adult White Sturgeon indexing program in 2010, 2012, 2015, 2018, and 2021.

Adult Indexing Study Year	Wanapum Catch FL (cm)					Priest Rapids Catch FL (cm)					All Catch FL (cm)				
	n	mean	SD	min	max	n	mean	SD	min	max	n	mean	SD	min	max
2010	**311**	104.1	15.1	58.0	132.5	**158**	101.3	14.3	64.5	132.5	**469**	103.2	14.9	58.0	132.5
2012[a]	**192**	115.1	16.2	62.5	144.0	**86**	113.9	14.3	79.0	141.0	**278**	114.7	15.6	62.5	144.0
2015	**291**	137.7	15.6	77.0	170.0	**98**	135.4	16.1	57.5	165.0	**389**	137.1	15.7	57.5	170.0
2018	**17**	134.2	30.7	81.5	178.7	**4**	133.4	17.5	107.2	144.0	**21**	134.0	28.3	81.5	178.7
2021	**16**	156.6	16.3	116.5	184.0	**4**	149.2	17.7	127	164.0	**20**	155.1	16.4	116.5	184.0

With the inclusion of the 2021 data, the combined adult indexing mark-recapture data set was sufficient to calculate POPAN model population estimates for the 2002BY in each reservoir. The resulting 2002BY population estimates in the Wanapum reservoir population decreased from 2,174 fish (95% CI = 1,454–3,251) in 2015, 125 fish (95% CI = 66–236) in 2018, to 86 fish (95% CI = 40–187) in 2021. The 2002BY population in Priest Rapids reservoir, estimated at 710 fish (95% CI = 475–1,061), decreased substantially to 22 fish in 2018 (95% CI = 12–24) and 22 (95% CI = 10–47) in 2021. The wide confidence intervals around the population estimates indicate the limitations of the model and underlying dataset; however, the low population estimates, in combination with the substantial reduction in catch numbers in both 2018 and 2021 compared to 2015 catch data, suggest a large decrease in abundance of the 2002BY population as a result of the 2002BY removal efforts.

Wild White Sturgeon

Similar to the 2002BY catch in 2021, the catch of wild fish in 2021 was nearly identical to the 2018 catch in both Wanapum and Priest Rapids reservoirs (Table 23). The 2018 catch of wild fish in Wanapum reservoir declined from 54 fish in 2015, to 8 fish in 2018 (i.e., 15% of the 2015 catch) to 7 fish in 2021 (i.e., 13% of the 2015 catch). Historically, very few wild fish have been caught in Priest Rapids reservoir with only 3 fish caught in 2015, 1 fish caught in 2018, and 1 fish caught in 2021. The seven wild White Sturgeon captured in 2021 in Wanapum reservoir were similar in size to fish caught in 2018, with a similar mean fork length and size range of fish caught. The single wild fish captured in Priest Rapids reservoir was 98 .0 cm FL and likely a juvenile. Though the age of this juvenile wild fish is not known, the size of this wild fish corresponds approximately to the dominant size class of the 2010BY and 2012BY fish. If the wild fish is with this age range (i.e., ~ age-10), this fish may have been spawned either in 2011 or 2012, both of which were very high flow years during which White Sturgeon population in the Columbia River Basin likely experienced high natural recruitment. All the wild fish were caught on large hooks, with seven of the eight wild fish captured on size 16/0 hooks and the remaining fish captured on a 14/0 hook.

Table 23 Catch and fork length of wild White Sturgeon captured in the Priest Rapids Project area during adult White Sturgeon indexing programs in 2010, 2012, 2015, 2018, and 2021.

Adult Indexing Study Year	Wanapum Catch FL (cm)					Priest Rapids Catch FL (cm)					All Catch FL (cm)				
	n	mean	SD	min	max	n	mean	SD	min	max	n	mean	SD	min	max
2010	**53**	169.8	31.3	116.0	241.0	**5**	166.4	34.4	137.5	205.0	**58**	169.6	31.3	116.0	241.0
2012	**30**	190.3	41.8	60.5	258.0	**3**	162.8	43.8	118.0	205.5	**33**	187.8	42.0	60.5	258.0
2015	**54**	198.4	36.9	81.0	256.0	**3**	139.3	65.4	65.5	190.0	**57**	195.3	40.3	65.5	256.0
2018	**8**	213.2	27.5	165.5	259.0	**1**	57.5	-	57.5	57.5	**9**	195.9	57.9	57.5	259.0
2021	**7**	198.6	31.7	148.0	252.0	**1**	98.0	-	98.0	98.0	**8**	186.1	46.1	98.0	252.0

With completion of the second adult indexing study since the 2002BY removal effort, the 2021 POPAN model population estimates of wild fish in Wanapum reservoir declined from 853 fish (95% CIs = 486–1,496) in 2015, immediately prior to the removal effort, to 100 fish (95% CIs = 41–242) in 2018 and 82 fish (95% CIs = 31–218) in 2021. Similarly, in Priest Rapids reservoir, where the wild fish population historically has been low, the wild population declined from 47 fish (95% CIs = 27–82) in 2015, to 12 fish (95% CIs = 5–30) in 2018 and 12 fish (95% CIs = 4–31) in 2021. The loss of a large proportion of the wild fish population in the PRPA was likely a consequence of the 2002BY removal effort. Based on 2015 length-frequency data of wild fish, 28% of the population sampled were within the target slot size selected for the 2002BY removal (Golder 2016). Given the substantial reduction in the wild population, it is possible that a proportion of wild fish larger and smaller than the slot size were inadvertently caught and removed during the removal effort. With the inadvertent reduction in the wild population, and that the abundance of the residual population of 2002BY is comparable to the remaining wild population, the risk of genetic swamping of the wild population by 2002BY still exists and likely has increased.

Seven of the eight wild fish encountered during the 2021 adult indexing study were new fish that were not encountered during previous indexing studies. The one recaptured wild fish (PIT tag number 985120021770455) was first captured by set line near Columbia Siding (RM451) in Wanapum reservoir on June 19, 2012 during broodstock capture efforts. In 2012, this fish was 199.5 cm FL long, weighed 69.4 kg, and was identified as a ripe flowing male (M2). The fish was implanted with an acoustic tag (ID 30695) and was transported to YNSH and spawned with a ripe female captured in Wanapum reservoir to contribute to the 2012BY released in the PRPA in 2013. The fish was returned to Wanapum reservoir in July 2012 and its movements tracked by acoustic telemetry array stations in Wanapum reservoir from 2012 to 2018 (Figure 30). After release, the fish exhibited regular seasonal movements between known overwintering areas near RM425 and RM442 and known spawning habitat in the tailrace of Rock Island Dam upstream of RM451. In 2021, the fish was captured immediately upstream of Sunland Estates near RM431. At recapture, the fish was 207 cm FL long and weighed 72.6 kg. As the fish was identified in the field as a mature male during the initial capture in 2012, a surgery was not conducted to determine its reproductive state in 2021.

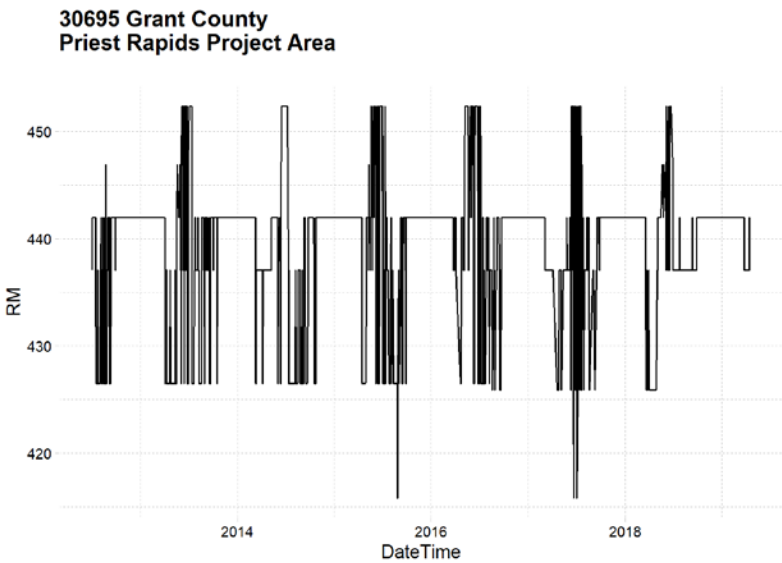

Figure 30 Seasonal movements of a previously captured and acoustic tagged wild White Sturgeon (Acoustic ID 30695) that was recaptured during the 2021 adult White Sturgeon population indexing program.

2010BY-2019BY

During the 2010 and 2012 indexing studies, prior to the majority of hatchery juvenile White Sturgeon releases in the PRPA, the catch composition consisted almost entirely of 2002BY and wild fish, with only incidental captures of juvenile hatchery fish in 2012 (n = 2; Golder 2013). By 2015, the older brood year releases, primarily the 2010BY and 2012BY, had grown and were captured in larger numbers on the adult sampling gear. In 2015, 2010BY to 2014BY hatchery White Sturgeon contributed 14% (75 of 532 fish; Golder 2016) to the total adult indexing catch. During adult indexing in 2018, after the 2002BY removal efforts and continued growth of the hatchery brood year releases, the 2010BY to 2017BY contributed 86% (206 of 239 fish) to the total catch. In 2021, the 2010BY to 2019BY, including unknown hatchery fish, contributed 94% to the total catch (415 of 443 fish). In Wanapum reservoir, population estimates of the 2010BY–2019BY based on capture-recapture data increased from 34 fish (95% CI = 7–158) in 2012 to 4,533 fish (95% CIs = 2,560–8,027) in 2021, as these fish recruited to the adult sampling gear. In Priest Rapids reservoir, the population estimates of the 2010BY–2019BY increased from 34 fish (95% CIs = 7–158) in 2012 to 1,571 fish (95% CIs = 887–2,782) in 2021, as these fish recruited to the adult sampling gear.

Overall, trends in length-frequency distribution, spatial distribution, and modeled population estimates of the 2010BY to 2019BY based on the analysis of the adult indexing data generally agreed with the same metrics examined as part of the juvenile indexing data analysis. Although the general trends in the adult and juvenile data sets are similar, and likely correspond to the underlying population attributes, the juvenile indexing analysis is based on a more robust dataset and provides a more definitive insight into the 2010BY to 2019BY population dynamics. As such, this discussion instead focuses on what information the adult indexing data provides to assess changes in the relative abundance of older brood years that are recruiting away from the juvenile gear.

Even though there are differences between the adult indexing gear (i.e., 3/8” ground line; 12/0, 14/0, and 16/0 hooks) and juvenile indexing gear (1/4” ground line; 2/0 and 4/0 hooks), the length-frequency and weight ranges of 2010BY-2019BY captured during the 2021 adult and juvenile indexing substantially overlapped and were nearly identical (see Figure 10; Figure 20). However, one difference between these datasets was evident for only the 2010BY, in that heavier fish were caught during adult indexing (mean = 11,413 g; n = 14) than during juvenile indexing (mean = 6,215 g; n = 36) for this brood year.

The only other notable difference between the 2021 adult and juvenile datasets was catch proportion by brood year. Catch proportion provides a coarse measure of the relative abundance among brood years. During juvenile indexing from 2016 to 2019, the catch proportion of the 2013BY was higher compared to other brood years, followed by 2014BY (Golder 2018, 2019, 2020). Over these studies, the catch proportion of 2013BY gradually declined and catch proportion of 2014BY gradually increased in each successive year and eventually exceeded the 2013BY in 2020 and 2021(see Figure 20). This change in the 2013BY catch proportion relative to the 2014BY was attributed to an increase in the mean fork length of the 2013BY and a reduced ability for small-hook juvenile sampling gear to catch fish over 100 cm FL (Golder 2021). Fish in these brood years over 100 cm FL would likely be more susceptible to capture by large hook set line sampling and likely caught in higher numbers during adult indexing. This was evident in the 2021 adult indexing catch, where the 2013BY catch proportion was higher compared to other brood years, followed by the 2014BY, and suggests that the relative abundance of 2013BY and 2014BY has not changed substantially since 2016.

Although the initial 2010BY release number (9,116 of 40,735 fish released since 2002) in the PRPA was the largest of all brood years released to date, the 2010BY are underrepresented in the adult and juvenile indexing catch. During 2021 adult indexing, the 2010BY were captured in the Project area in lower numbers (14 of 443 fish; 3.2%) than during the 2018 adult indexing study (19 of 236 fish; 8.1%), both of which were notably lower than the catch during the 2015 adult indexing study (60 fish of 532 fish; 11.3%). Similarly, catch of 2010BY in the PRPA during juvenile indexing studies in 2017 (61 fish of 568 fish; 11.3%), 2018 (43 of 563 fish; 7.6%), 2019 (40 of 639 fish; 6.3%), 2020 (31 of 627 fish; 4.9%), and 2021 (37 of 924 fish; 4.0%) decreased each successive year and were notably lower than the 2010BY catch in 2016 (123 of 828 fish; 14.9%). The low recapture rate of 2010BY in 2021 also likely contributed to the wide confidence intervals of the POPAN model survival estimate of the 2010BY to 2019BY as a group (see Figure 11). The decrease in 2010BY catch during juvenile indexing after 2016 was possibly due to fish recruiting away from the juvenile gear and recruiting to the adult indexing gear; however, the adult indexing catch only decreased over this time period as well. Overall, the 2010BY catch after 2016 decreased substantially and this suggests that a proportion of the 2010BY population was removed during the 2002BY removal efforts. The apparent ongoing decline in the 2010BY population may also be due to other factors that affect survival in the PRPA.

4.4 Juvenile Indexing Sampling Effort and Catch

The 2021 juvenile White Sturgeon population indexing study design and sample effort was consistent with previous indexing studies conducted annually since 2016. This consistency could make it easier in future study years to identify environmental variables that affect the abundance and distribution of the juvenile White Sturgeon in the PRPA. A total capture of 924 fish in 2021 (i.e., 754 fish captured in Wanapum reservoir and 170 fish captured in Priest Rapids reservoir) exceeds the catch of all previous study years. The 2021 catch consisted of 911 2010BY–2019BY, 4 2002BY, and 9 wild fish. Since the start of systematic indexing in 2016, 4,204 White Sturgeon have been captured in the PRPA (Table 24).

The higher catch in 2021 compared to other juvenile indexing studies did not appear to be related to any obvious environmental variable. The 2021 study was conducted slightly later in the year (i.e., September 27 to October 23) than previous juvenile indexing surveys (i.e., typically from early September to early October). Substantial flow fluctuations and changes in reservoir level during sampling were frequent and may have displaced fish or resulted in increased fish movement between habitats. Lower flows occurred while sampling the upper section of Wanapum reservoir upstream of RM446 and allowed deployment of set lines at locations in the portion of the reservoir that are typically either too deep or too fast to sample at high flows; a moderate number of fish were captured at these site (n = 31, see Figure 17).

Table 24 White Sturgeon catch by reservoir in the Priest Rapids Project area during juvenile White Sturgeon indexing conducted from 2016 to 2021.

Study Year	Wanapum Reservoir Catch	Priest Rapid Reservoir Catch	Total Catch
	n	n	n
2016	746	141	887
2017	490	78	568
2018	454	109	563
2019	566	73	639
2020	484	143	627
2021	754	170	924
All Years	**3,494**	**710**	**4,204**

4.4.1 Catch Distribution by Brood Year and Reservoir

Wanapum reservoir

In 2021, the 2014BY contributed the largest portion of the catch in Wanapum reservoir (25%; 189 of 754 fish), followed by the 2013BY (15%; 116 of 754 fish). In 2020, the 2014BY also contributed the largest portion of the catch in Wanapum reservoir (24%; 116 of 484 fish), followed by the 2013BY (19%; 90 of 484 fish). During study years prior to 2020, the 2013BY were consistently captured in greater numbers than other brood years. The lower catch proportion of the 2013BY in 2020 and 2021 in relation to the 2014BY was attributed to a gradual reduction in catchability of the 2013BY as opposed to a change in population abundance. As the 2013BY increased in size, the effectiveness of the small hook set line gear to capture these older, larger fish was reduced (i.e., greater ability to bend and straighten hooks; Golder 2021).
From 2017 to present, the catchability of 2010BY and 2012BY with small hook set line gear

likely also gradually reduced as these fish increased in size, with lower catch proportions in 2021 (2010BY 3%; 2012BY 8%) compared to 2017 (2010BY 10%; 2012BY 14%; Golder 2018).

The 2015BY, 2016BY, and 2017BY, which were released in nearly identical numbers, contributed similar proportions to the total catch in 2021 (2015BY n = 79; 2016BY n = 31; 2017BY n = 95) as they did in 2020 (2015BY n = 62; 2016BY n = 10; 2017BY n = 72), and 2019 (2015BY n = 42; 2016BY n = 10; 2017BY n = 60). These catch proportions likely reflect their relative abundance in Wanapum reservoir. Based on change in catch since release, both the 2015BY and 2017BY were caught in substantially higher numbers after 1.5 years to 2.5 years at large, had grown in size, and were more susceptible to capture with the juvenile indexing gear (Golder 2021). Similarly in 2021, the 2018BY, also recruited strongly to the juvenile sampling gear after approximately 2.5 years at large. Both the 2017BY (n = 95) and 2018BY (n = 90), which were released in similar numbers (2018BY 1,767 fish; 2017BY 1,983 fish), were captured in similar numbers in 2021 and likely have similar survival rates. The 2016BY were detected in highest numbers to date in 2021 (31 fish) compared to 2020 (10 fish) and single digit catches in all previous indexing studies. The low abundance of the 2016BY in Wanapum reservoir potentially indicates low post-release survival or high emigration out of the Project area (Golder 2020).

In 2021, Ep for Wanapum reservoir was 0.74 and exceeded the previous highest Ep of 0.70, which was recorded in 2019 (Golder 2020). Prior to 2020, the highest Eps by reservoir section were generally recorded in the middle section of Wanapum reservoir, with slightly lower Eps in the upper section, and the lowest Eps in the lower section. The change in Ep was mirrored by similar changes in CPUE in each reservoir section. From 2020 onward, the highest Eps by reservoir section have been recorded in the upper section (2020 Ep = 0.73; 2021 Ep = 0.83), with slightly lower Eps in the middle section, and the lowest Eps in the lower section. The shift in Ep and catch distribution to the upper section of Wanapum reservoir appears to be due to an increase in fish use between RM434 and RM442 and a corresponding decrease in fish use of deep-water habitat in the middle section.

In 2021, the 2013BY and 2014BY were the most broadly dispersed brood years and were found at generally higher Eps in the lower, middle, and upper sections of Wanapum reservoir compared to other brood years, which was consistent with the distribution of these two brood years recorded from 2017 to 2020 (Golder 2018). In 2021, the highest Eps were recorded for the 2012BY, 2014BY, 2015BY, and 2018BY in the upper section of Wanapum reservoir. A similar trend was recorded in 2020 (Golder 2021). Prior to 2020, the Ep of the 2010BY, 2012BY, and 2017BY was highest in the upper section, whereas the Eps of the other brood years were higher in the middle and/or lower sections (Golder 2020). Additional catch data in future indexing studies will confirm whether the shift to higher Eps in the upper section, as recorded in both 2020 and 2021, is indicative of a long-term shift in fish distribution.

Priest Rapids reservoir

Due to the smaller size of Priest Rapids reservoir, in both total length and volume, the reservoir is allocated 25% of the sample effort in the PRPA. Since the start of hatchery releases of juvenile White Sturgeon in the PRPA, the proportion of juvenile hatchery fish released into Priest Rapids has varied between 23% and 38% of the total annual releases. That said, relative abundance among brood years within Priest Rapids reservoir would be expected to align with trends observed in Wanapum reservoir and any substantial deviation in trends may relate to different environmental conditions between the two reservoirs that could affect survival and abundance. As documented in previous indexing studies (Golder 2020), a substantial proportion of the fish captured in Priest Rapids reservoir were entrained from upstream reservoirs (e.g., Wanapum reservoir). In 2021, as well as in previous indexing years, approximately 50% of the 2013BY captured in Priest Rapids reservoir were fish that were entrained from Wanapum reservoir. Similar to Wanapum reservoir, reduced catchability of older, larger hatchery brood years was also evident in the catch of these brood years in Priest Rapids reservoir.

In Priest Rapids reservoir, the 2021 catch (n = 170) exceeded all previous catches from previous indexing studies in 2020 (n = 143), 2019 (n = 73), 2018 (n = 109), 2017 (n = 78), and 2016 (n = 141). Total catch has varied considerably among study years, with the catch from one or two high use areas contributing a high proportion of the total catch. In indexing years with low catch, the reduced catch was due in part to random chance and that sample sites were not selected in high use areas. Overall, the catch proportion among brood years has remained consistent. In 2016, the 2010BY were captured in the highest catch proportion of all brood years. After the 2002BY removal effort in 2015 and 2016, which likely also captured some 2010BY fish, the 2013BY were the predominant brood year in the catch composition in 2017 (25%; 20 of 78 fish), 2018 (29%; 32 of 109 fish), 2019 (26%; 19 of 78 fish) and 2020 (24%; 34 of 143 fish) with all other brood years individually contributing 21% or less to the catch. In 2021, the catch proportion between 2013BY (22%; 37 of 170 fish) and 2014BY (20%; 34 of 170 fish) were nearly equal and suggests the 2013BY are recruiting away from the juvenile indexing gear with the result that the 2014BY will likely be the dominant brood year in future studies. Catch proportions between the 2015BY, 2016BY, 2017BY, and 2018BY in Priest Rapids reservoir were similar to the catch proportions in Wanapum reservoir for these brood years; however, due to the low number of fish captured, catch proportion among these brood years can vary substantially among study years.

The Ep for Priest Rapids reservoir in 2021 was 0.51. The highest Ep in Priest Rapids reservoir was recorded in 2016 (Ep = 0.53), with lower values recorded in 2017 (Ep = 0.39), 2018 (Ep = 0.41), 2019 (Ep = 0.33), and 2020 (Ep = 0.44). The Ep among the reservoir sections can vary substantially. In 2021, the highest Ep was recorded in the upper (Ep = 0.60) and lower (Ep = 0.6) sections, with a lower Ep recorded in the middle section (Ep = 0.33). Similarly, in 2020, the upper (Ep = 0.50) and lower (Ep = 0.47) sections had similar Eps that were higher than the middle section (Ep = 0.37). However, in 2021, the CPUE in the lower (CPUE= 0.18 fish/100 hook-hours) and middle (CPUE= 0.16 fish/100 hook-hours) were similar and lower than the upper section (CPUE= 0.32 fish/100 hook-hours). The CPUE in context with Ep values indicates that most set lines in the lower section caught only one or two fish, while in the middle section, most of the fish were caught on one or two set lines. Lower use of the middle section of Priest Rapids reservoir by sturgeon may be due to higher water velocities compared to the upstream and downstream sections.

4.4.2 Juvenile White Sturgeon Population Estimates

With the inclusion of the 2021 data into the CJS model, the brood-year specific survival estimates varied between Priest Rapids reservoir and Wanapum reservoir to support a model that included reservoir of capture as an explanatory variable factor. This result allowed use of model-averaged estimates for each reservoir to estimate brood year survival in first year after release (i.e., less than one year at large) and for all subsequent years (i.e., greater than 1 year at large).

For each reservoir, separate survival estimates were possible for all brood years that were at large for one or more years. First year survival was lower in Priest Rapids reservoir than in Wanapum reservoir for all brood years, with the exception of the 2010BY population in Priest Rapids, which had the highest first year survival of all brood years in the PRPA. Consistent with previous model estimates, the low first year survival of the 2016BY was supported by the empirical catch data of this brood year in both reservoirs. Although more 2016BY were captured in Wanapum reservoir (n = 31) than in previous indexing years, the 2016BY remain underrepresented in both reservoirs. The low first year survival estimates of the 2016BY may have been the result of higher mortality (vs emigration) due to their small size at release, as this brood year release was below average weight at release (2016BY mean = 126 g; 2010BY–2019BY mean = 205 g), but more likely due to a higher rate of emigration based on entrainment of 25% of the acoustic-tagged 2016BY juveniles post-release from Wanapum reservoir, which was the highest rate of all brood year releases (Golder 2018). The highest first year survival in Wanapum reservoir was the 2017BY (0.360), with similar survival for the 2018BY-2019BYa fish. In Priest Rapids reservoir, the 2017BY had lower survival (0.08) than the 2017BY released in Wanapum reservoir (0.360). This difference in 2017BY first year survival may be due to a lower weight at release of 2017BY in Priest Rapids reservoir (mean = 136 g) compared to the 2017BY released in Wanapum reservoir (mean = 150 g). For comparison, the difference in first-year survival of 2018BY in Wanapum (0.357) and in Priest Rapids (0.219) was less and possibly due to the mean weights of the two release 2018BY groups being nearly equal (130g in Wanapum vs 124 g Priest Rapids; see Table 16).

Survival rates increased for all brood years after one year at large in both reservoirs. Inclusion of the 2002BY removal efforts on the 2010BY survival as a variable in the 2021 model allowed modelling of two different post-first year survival estimates for the 2010BY. The 2010BY survival in the absence of 2002BY removal was 0.98 or greater for each reservoir. During the removal years, the 2010BY survival estimates decrease substantially in Priest Rapids reservoir (0.443) compared to Wanapum reservoir (0.786). Parsing out the effect of the 2002BY removal effort on 2010BY survival allowed a more realistic estimate of post-removal 2010BY survival and the contribution of the 2010BY to the current PRPA population.

With the inclusion of the 2021 catch data and updating of the model, population estimates were generated for the 2011–2021 study years (see Table 19). A comparison of the 2019 population estimates by reservoir between the 2021 model and the previous 2020 model was conducted (Golder 2021). The 2020 model population estimate for Wanapum reservoir in 2019 was 7,417 fish, whereas the 2021 model 2019 population estimate in Wanapum reservoir was slightly higher, at 7,639 fish. Conversely, the 2020 model results for Priest Rapids reservoir in 2019 was 3,291 fish, whereas the 2021 model estimated the 2019 population estimate in Priest Rapids reservoir lower at 2,042 fish. In both models (2020 and 2021 models), the 2020 population estimates decreased in both reservoirs as the smaller release size of the 2019BY in 2020 (n = 672) was not sufficient to compensate for the mortality of previously released fish. In 2021, the annual hatchery release was higher (n = 1,485), but less than previous annual releases under the SOA (i.e., 3,250 fish). The 2021 model also took into account the effect of the 2002BY removal efforts and differential survival of the 2010BY. The 2021 juvenile indexing population estimates of hatchery fish abundance in Wanapum reservoir increased in 2021, compared to previous 2020 estimates, and was 8,292 (95% CI = 6,748–9,836) or 29% of total hatchery releases to date (28,489 fish). In Priest Rapids reservoir, the 2021 hatchery fish abundance estimate was 2,408

(95% CI = 1,744–3,073) or 20% of total hatchery releases to date (12,256 fish), which was an increase compared to 2020.

4.5 Growth

Substantial variation in growth among individuals within individual brood years was evident in previous indexing studies and is well documented (Golder 2017–2021). Similar to previous indexing studies, the 2021 length-frequency histograms of most brood years substantially overlapped, with the exception of the oldest (i.e., 2010BY) and youngest fish (i.e., 2019BYa&b). In the length-frequency histogram of older brood years, a decrease in catch frequency of fish over 90 cm FL likely represents the maximum effective capture size for the juvenile indexing set line gear, in that fish greater than 90 cm FL were more likely to straighten hooks, reducing their catchability (Golder 2021).

Based on regression of log weight and log length, growth rates in Wanapum reservoir and Priest Rapids reservoir were nearly identical based on the combined adult and juvenile indexing datasets. However, when growth rate was examined by age, the growth rate of age-6 and older fish in Priest Rapids slowed substantially compared to fish in Wanapum reservoir. In 2020, lower relative weights were recorded for the 2010BY, 2012BY, 2017BY, and 2019BY in Wanapum reservoir. These brood years were captured in greater numbers in the upper section of Wanapum reservoir, which is more riverine than the downstream sections, and the low relative weight of these brood years was assumed to be a consequence of the higher energetic costs required to inhabit this section of the river. In 2021, below average relative weights were only evident in the 2013BY and 2018BY. Given the change in findings between the 2020 and 2021 indexing studies, annual variation in relative weight for a given brood year may be more complex and involve other environmental variables in addition to variables related to energetic cost.

In 2020, mean growth rates of all brood years were highest in the lower section, lower in the middle section, and lowest in the upper section of each reservoir. This trend in growth was also evident in the 2021 data. The difference in growth among reservoir sections was assumed to be due to, 1) greater energetic expense by fish in the upper and middle sections compared to fish in the lower section of the reservoir and, 2) possible density dependent growth in the upper section of each reservoir as a result of higher use of these sections by larger numbers of sturgeon compared to the middle and lower sections. A detailed examination of these growth data was conducted in 2020 (Golder 2021). In 2021, inclusion of an additional year of growth data was not sufficient to expand on or refute the 2020 findings, which concluded that density dependent growth was not evident based on growth rates estimated for each brood year for the entire population of hatchery-reared sturgeon in the Project area. In Wanapum reservoir, growth rates of the brood year releases examined did not exhibit clear signs of density-dependent growth. In Priest Rapids reservoir, growth rates were lower than rates in Wanapum reservoir and large differences in growth were observed between brood years. The extent of density-dependent growth remains unclear. If density does affect growth, reduced growth may be limited to fish occupying the upper reservoir section and to fish occupying the Wanapum Dam tailrace area.

4.6 Alternative Stocking Strategy for Priest Rapids reservoir

An alternate stocking strategy was developed and implemented in 2021 in Priest Rapids reservoir to address potential issues related to density dependent growth of hatchery fish released into the Wanapum Dam tailrace area. Sturgeon densities are known to be high in the upper section of Priest Rapids reservoir (see Table 14 and Figure 17) and juvenile fish in the Wanapum Dam tailrace area may potentially compete with older and larger juveniles from previous brood year releases that did not disperse downstream. Consequently, newly released fish could experience lower growth due to density-dependent factors such as increased competition for limited food resources. By releasing fish at a downstream location, it was presumed space and resources would be less limited and fish would have the opportunity to move upstream and disperse more evenly throughout the reservoir. Based on access and logistic considerations, the Priest Rapids Recreation Area boat launch (RM400.3) was selected as the new release site in Priest Rapids reservoir. All 2019BYb were released at this location on April 20 and upstream dispersal of these fish was confirmed through the capture of 2019BYb fish in the upper section of Priest Rapids reservoir during the 2021 adult indexing study.

4.7 Summary

In 2021, the balance of the 2019BYb fish were released into the Project area at the Vantage boat launch in Wanapum reservoir and the Priest Rapids Recreation Area boat launch in Priest Rapids reservoir. Broodstock collection was successfully completed to produce a 2021BY based on a 6Fx6M spawning matrix using fish captured in John Day reservoir.

Capture and recapture sessions of Adult White Sturgeon indexing were conducted from August 16 to September 18. In total 443 fish were captured. Juvenile hatchery fish represented 415 of the 443 fish captured. In total, 8 wild fish (7 adults; 1 subadult) and 20 2002BY adults were also captured during adult indexing. The 2002BY were mature and both ripe female and male fish of this brood year were identified. Combined with existing adult indexing data from 2010, 2012, 2015, 2018, and 2021, data were sufficient to obtain POPAN population estimates for three groups; the 2002BY, 2010BY–2019BY, and wild fish. Other metrics, like catch proportion, length-frequency, CPUE, and Ep estimates, were calculated for each brood year to infer differences in survival and abundance among groups and to support the POPAN population model results. Adult capture data were used to assess the extent older hatchery fish recruit from the small-hook juvenile set line gear to the adult gear. With completion of the second adult indexing study since the 2002BY removal effort, the 2021 POPAN model population estimates of wild fish in Wanapum reservoir declined from 853 fish (95% CIs = 486–1,496) in 2015, immediately prior to the removal effort, to 100 fish (95% CIs = 41–242) in 2018, to 82 fish (95% CIs = 31–218) in 2021. Similarly, in Priest Rapids reservoir, where the wild fish population historically has been low, the wild population declined from 47 fish (95% CIs = 27–82) in 2015, to 12 fish (95% CIs = 5–30) in 2018, to 12 fish (95% CIs = 4–31) in 2021. The loss of a large proportion of the wild fish population in the PRPA was likely a consequence of the 2002BY removal effort.

Juvenile White Sturgeon indexing conducted in 2021 captured 924 fish and exceeded all previous annual catches. The juvenile White Sturgeon Cormack-Jolly-Seber (CJS) population model was revised to calculate survival probability estimates and recapture probabilities by brood year to estimate total White Sturgeon populations for each reservoir by calendar year. Other metrics, like catch proportion, length-frequency, CPUE, and Ep estimates, were calculated for each brood year to infer differences in survival and abundance among groups and to support the CJS population model results. Two separate survival estimates were generated for the 2010BY to account for loss of individuals taken as bycatch during the 2002BY removal effort. To account for the reduction in captures of larger fish as fish recruited away from the juvenile gear, the recapture rate was allowed to vary with age. This specification of the model accounted for change in recapture rates between brood years, and informed the model, so that survival of older brood years was not artificially deflated due to fish recruiting away from the gear. Future juvenile indexing studies will continue to address sample gear bias by assessing the size selectivity of the juvenile sampling gear.

Mean annual growth rates recorded in 2021 for each hatchery brood year were comparable to rates recorded during previous study years. In 2021, higher growth rates were recorded in Wanapum reservoir than in Priest Rapids reservoir. Lower growth rates were evident for individuals of brood years that resided in the upper sections of each reservoir and was assumed to relate to higher energetic cost and possibly to density dependent growth. Density dependent growth of fish was not evident in Wanapum reservoir in 2021. In Priest Rapids reservoir, growth was slower for fish older than age-6; however, it was unclear if the reduce growth rate was density dependent. Historically, in Priest Rapids reservoir, all juvenile White Sturgeon were released into the upper section of the reservoir and this release strategy was considered as a possible reason why growth rates were notably lower for fish older that age-6 in Priest Rapids reservoir when compared to Wanapum reservoir. An alternative release strategy for Priest Rapids reservoir was implemented in 2021 to address this risk and the 2019BYb were successfully released at Desert Aire in the lower section of Priest Rapids reservoir. Based on evidence that 2019BYb dispersed upstream after release, all future juvenile hatchery releases should be released into Priest Rapids reservoir at the Priest Rapids Recreation Area boat launch.

Literature Cited

Bannerot, S.P. and C.B Austin. 1983. Using frequency distributions of catch per unit effort to measure fish-stock abundance. Journal: Transactions of The American Fisheries Society - TRANS AMER FISH SOC , vol. 112, no. 5, pp. 608-617, 1983

Beamesderfer, R.C. 1993. A standard weight (Ws) equation for white sturgeon. California Fish and Game 79:63-69.

Bruch, R. M., T. A. Dick, and A. Choudhury. 2001. A field guide for the identification of stages of gonad development in lake sturgeon (Acipenser fulvescens). Sturgeon for Tomorrow, Fond du Lac, Wisconsin. 38 pp.

Counihan, T. D., M. J. Parsley, D. G. Gallion, C. N. Frost, and Morgan. February 1999. Report C. 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, April 1997-March 1998, Report C in 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, April 1997-March 1998. Ward, D. L. (ed.), Portland, OR: Oregon State University, 94-129.

DART. 2021. Columbia River Data Access in Real Time webpage. DART hourly water quality data RIGW www.cbr.washington.edu/dart/river.html

Golder Associates Inc. 2011. White sturgeon monitoring and evaluation program annual report 2010. Report prepared for Public Utility District No. 2 of Grant County, Ephrata, Washington. Golder Associates Ltd. Report No. 10-3930-0300: 42pp. + 7 app.

Golder Associates Ltd. 2013. Waneta White Sturgeon Spawn Monitoring: 2012 Investigations. Data Report prepared for Columbia Power Corporation, Castlegar, BC. Golder Report No. 12-1492-0031

Golder Associates Inc. 2015. White sturgeon management plan annual data report 2014. Report prepared for Public Utility District No. 2 of Grant County, Ephrata, Washington. Golder Associates Ltd. Report No. 10-3930-0304: 57pp. + 6 app.

Golder Associates Inc. 2016. White sturgeon management plan annual data report 2015. Report prepared for Public Utility District No. 2 of Grant County, Ephrata, Washington. Golder Associates Ltd. Report No. 10-3930-0305: 62pp. + 2 app.

Golder Associates Inc. 2017. White sturgeon management plan annual data report 2016. Report prepared for Public Utility District No. 2 of Grant County, Ephrata, Washington. Golder Associates Ltd. Report No. 10-3930-0306: 68pp. + 1 app.

Golder Associates Inc. 2018. White Sturgeon Management Plan Annual Report and Year 10 Biological Objective Status Report. Report prepared for Public Utility District No. 2 of Grant County, Ephrata, Washington. Golder Associates Ltd. Report No. 10-3930-0306: 51 pp. + 4 app.

Golder Associates Inc. 2019. White Sturgeon Management Plan Annual Report and Year 10 Biological Objective Status Report. Report prepared for Public Utility District No. 2 of Grant County, Ephrata, Washington. Golder Associates Ltd. Report No. 1899247: 74 pp. + 1 app.

Golder Associates Inc. 2020. White Sturgeon Management Plan Annual Report. Report prepared for Public Utility District No. 2 of Grant County, Ephrata, Washington. Golder Associates Ltd. Report No. 189924701: 60 pp. + 2 app.

Golder Associates Inc. 2021. White Sturgeon Management Plan Annual Report. Report prepared for Public Utility District No. 2 of Grant County, Ephrata, Washington. Golder Associates Ltd. Report No. 189924702: 74 pp. + 1 app.

Justice, C., Pyper, B.J., Beamesderfer, R.C.P., Paragamian V.L., Rust, P.J., Neufeld, M.D., Ireland, S.C. 2009. Evidence of density- and size-dependent mortality in hatchery-reared juvenile white sturgeon (Acipenser transmontanus) in the Kootenai River. Canadian Journal of Fisheries and Aquatic Sciences, 2009, 66:802-815.

Kincaid, T. 2007. User guide for spsurvey version, 1.6: probability survey design and analysis functions. Available at: http://www.epa.gov/nheerl/arm/analysispages/software.htm.

Laake, J.L. 2013. RMark: An R interface for analysis of capture-recapture data with MARK. AFSC Processed Rep 2013-01, 25p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

NOAA. 2021. https://www.nwrfc.noaa.gov/water_supply/ws_normals.cgi?id=RISW1

Ogle, D.H., P. Wheeler, and A. Dinno. 2020. FSA: Fisheries Stock Analysis. R package version 0.8.31, https://github.com/droglenc/FSA.

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Stevens Jr., D.L. and Olsen, A.R. 2004. Spatially Balanced Sampling of Natural Resources. Journal of the American Statistical Association, 99, 262-278.Uphoff, J. H., Jr. 1993. "Determining Striped Bass Spawning Stock Status from the Presence or Absence of Eggs in Ichthyoplankton Survey Data." North American Journal of Fisheries Management 13(4): 645-656.

Uphoff, J. H., Jr. 1993. "Determining Striped Bass Spawning Stock Status from the Presence or Absence of Eggs in Ichthyoplankton Survey Data." North American Journal of Fisheries Management 13(4): 645-656.

Upper Columbia White Sturgeon Recovery Initiative (UCWSRI). 2006. Columbia River Adult White Sturgeon Capture, Transport and Handling Manual. May 2006 Version. 21pp + 5

White, G. C. and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46:120-139.

Wickham, H. 2009. ggplot2: elegant graphics for data analysis. Springer New York Bannerot, S. P. and C. B. Austin (1983). Using Frequency Distributions of Catch per Unit Effort to Measure Fish-Stock Abundance. Transactions of the American Fisheries Society 112: 608-617.

Appendix A
2021 White Sturgeon Broodstock Collection Grant County PUD and Blue Leaf Environmental

MEMORANDUM

TO: Mike Clement, Grant County PUD

FROM: Corey Wright, *Blue Leaf Environmental*

DATE: August 4th, 2021

SUBJECT: Broodstock Collection Below McNary Dam in 2021

Following a suspension of broodstock collection in 2020 the effort resumed this year. For the first time since the beginning of the program only Grant County PUD funded the effort as Chelan PUD began their wild larval collection program. This year like past years fishing took place in the spawning sanctuary below McNary dam on the Columbia River over ten days, May 17th to May 21th and from May 24th to May 28th. Flows during this time were between 200 kcfs and 230 kcfs, which is below the 10 year mean by ~127 kcfs. River temperatures ranged from 13.1°C to 14.1°C, the mean temperature was 13.3°C which is 0.2°C above the 10 year mean.

There were 87 individual white sturgeon captured and 4 fish were captured twice for a total of 91 sturgeon landings. The mean number of fish captured per day was 9 while the mean per day per boat was 4.6 up slightly from the 2012-2019 mean per day per boat of 4.5. There were 56 individual white sturgeon over 150 cm or mature spawning size were captured and 2 fish were captured twice for a total of 58 >150cm sturgeon landings. As a part of ODFW's spawning study acoustic tags were implanted in 5 males and 4 F3 females for a total of 9 tags released during the effort. For the broodstock collection effort 6 ripe females and 6 ripe males were transported to Marion Drain Hatchery. On the 10th of June a 6x6 spawning matrix was attempted, one female only produced enough eggs for two families resulting in 32 families

This year three sturgeon previously transported to the hatchery were recaptured, one female and two males. The first male was captured and transported to the hatchery in 2014 prior to recapture this year. The second male was transported to the hatchery in 2014 and has been recaptured three times since in 2015, 2019 and 2021. The female was first captured twice in 2015, then transported to the hatchery in 2016 before subsequently being recaptured post spawn in both 2018 and now 2021.

ACKNOWLEDMENTS

Blue Leaf Environmental thanks the staff of Grant PUD for allowing us to assist them in this effort. We also thank Dan and Neil Sullivan of Rivers West Sport Fishing, Stuart Hurd from Hurd's Guide Service for all their fishing services and expertise. Donella Miller and the staff at Marion Drain Hatchery for assisting with transported fish and undertaking the spawning effort. The many fishing volunteers without which fish would not get landed. We finally thank ODFW and WDFW and there permitting staff for assistance executing permits.

Table 1 . Catch data from white sturgeon broodstock collection efforts below McNary Dam in 2021.

No.	Date	Sex Code	Length (mm)	Girth (cm)	Fate	Event Type	Mark @ Cap	PIT Tag
1	05/17/2021	M5	2440	950	R2R	Mark	none	3DD.003D560357
2	05/17/2021	F6	2390	1020	R2R	Mark		3DD.00778F1C5B
3	05/17/2021	F3	2510	910	R2R	Recapture	L2	3DD.007790F4AF
4	05/18/2021	JUV	1540	620	R2R	Recapture		3DD.0077913E73
5	05/18/2021	JUV	1340		R2R	Recapture		3D9.1C2DF1A5D0
6	05/18/2021	JUV	1110	480	R2R	Recapture	L2	3DD.007783F588
7	05/18/2021	M5	2140	860	Hatchery	Mark		3DD.007790D752
8	05/18/2021	F4	2230		R2R	Recapture	L2	3D9.1C2D2F67A7
9	05/18/2021	M5	1820	780	Hatchery	Mark		3DD.00779111FF
10	05/18/2021	M5	1950	830	Hatchery	Mark		3DD.00779125F2
11	05/18/2021	M1-4	1950	770	R2R	Recapture	L2,9	3D9.1BF10ECCBD
12	05/19/2021	JUV	1400	580	R2R	Mark		3DD.003D56035C
13	05/19/2021	F3	1970	820	R2R	Recapture	L2	3D9.1C2CDA14E4
14	05/19/2021	M5	2170	920	Hatchery	Mark	L3,13	3DD.00778F462A
15	05/19/2021	F3	2360	1060	R2R	Mark		3DD.00778F7E89
16	05/19/2021	F5	2540	1110	Hatchery	Mark		3DD.0077912259
17	05/19/2021	M1-4	2430	1020	R2R	Recapture	L2	3D9.1C2DF796E3
18	05/19/2021	M1-4	1970	740	R2R	Mark		3DD.00778F37F7
19	05/19/2021	M1-4	1410	570	R2R	Recapture	L2	3D9.1C2DC9A43B
20	05/19/2021	M5	1950	830	Hatchery	Recapture	L2	3D9.1BF10DEB68
21	05/19/2021	M5	2030	880	Hatchery	Recapture	L1,2,8,12,20,22	3D9.1BF10DFB61
22	05/20/2021	JUV	1430	620	R2R	Mark	L10,R9	3DD.003D560354
23	05/20/2021	JUV	1050	440	R2R	Mark		3DD.003D560359
24	05/20/2021	F5	2620	1170	Hatchery	Mark		3DD.0077913F49
25	05/20/2021	F5	2230	1000	Hatchery	Mark		3DD.007790F959
26	05/20/2021	JUV	1550	620	R2R	Mark		3DD.007790D8FB
27	05/20/2021	M1-4	2330	970	R2R	Mark	L4	3DD.00778F43AF
28	05/20/2021	M5	2370	890	R2R	Recapture	L2,9,18	3D9.1BF10D351F
29	05/20/2021	JUV		630	R2R	Recapture	L2	3D9.1C2DF47227
30	05/20/2021	M5	2240	970	R2R	Recapture	L2	3D9.1BF2343C2B
31	05/21/2021	JUV	1440	620	R2R	Mark		3DD.003D560363
32	05/21/2021	JUV	1400	600	R2R	Mark		3DD.003D560354
33	05/21/2021	JUV	1330	510	R2R	Recapture	L2,15,16,20,21 R17,26	3D9.1C2D7981D5
34	05/21/2021	JUV	1270	510	R2R	Recapture	L2	3D9.1BF10E2975
35	05/21/2021	JUV	1260	530	R2R	Recapture	L3	3DD.0077533489
36	05/21/2021	JUV	1100	470	R2R	Recapture	L2,R9	3DD.0077C85E45
37	05/21/2021	JUV	900	360	R2R	Recapture		3DD.0077A0F2A9
38	05/21/2021	JUV	690	320	R2R	Mark		3DD.003D560360
39	05/21/2021	JUV	1710	670	R2R	Mark		3DD.0077915A39
40	05/21/2021	M1-4	2400	1080	R2R	Mark		3DD.00778F4DAD
41	05/21/2021	JUV	1740	700	R2R	Recapture		3DD.0077636818
42	05/21/2021	JUV	1820	720	R2R	Mark	L9,R2	3DD.0077909760
43	05/21/2021	M5	2460	90	R2R	Mark		3DD.007783FED0
44	05/24/2021	JUV	1700	720	R2R	Recapture	L2,9	3D9.1BF10E17AD
45	05/24/2021	JUV	1110	450	R2R	Recapture	L2,R9	3DD.0077906EFB
46	05/24/2021	JUV	870	330	R2R	Mark		3DD.003D56036B
47	05/24/2021	JUV	760	300	R2R	Mark		3DD.003D56038A
48	05/24/2021	JUV	1570	580	R2R	Recapture	L2	3D9.1C2CDACDE1
49	05/24/2021	M5	2160	770	R2R	Recapture	L2	3D9.1C2E0AAFE4
50	05/24/2021	F4	2580		R2R	Mark	L2,6,R2	3DD.007790BD62
51	05/25/2021	JUV	1550	600	R2R	Recapture	L2	3DD.0077906271
52	05/25/2021	JUV	1270	450	R2R	Mark		3DD.003D56038D
53	05/25/2021	JUV	1230	520	R2R	Mark	L10	3DD.003D56034E
54	05/25/2021	JUV	1190	490	R2R	Mark		3DD.003D560391
55	05/25/2021	JUV	1150	490	R2R	Mark		3DD.003D56034A
56	05/25/2021	JUV	1000	420	R2R	Mark		3DD.003D560377
57	05/25/2021	JUV	930	350	R2R	Recapture	L2,21	3DD.003D56036B
58	05/25/2021	JUV	560	220	R2R	Recapture	L2	3DD.0077CCE3F1
59	05/25/2021	F5	2570	1040	R2R	Recapture	L2	3DD.0077536116

No.	Date	Sex Code	Length (mm)	Girth (cm)	Fate	Event Type	Mark @ Cap	PIT Tag
60	05/25/2021	M1-4	2270	870	R2R	Recapture	L2	3DD.007753466E
61	05/25/2021	M5	2400	900	R2R	Recapture	L2,R3	3DD.0077907ABD
62	05/25/2021	M5	2400	870	R2R	Mark		3DD.0077904B4A
63	05/25/2021	M5	2470	870	R2R	Recapture	L2	3D9.1C2DF14F1B
64	05/25/2021	M5	1820	770	R2R	Mark		3DD.00778F6679
65	05/25/2021	F5	2430	1160	Hatchery	Mark		3DD.007790B632
66	05/26/2021	JUV	1510	560	R2R	Recapture	L2,R3	3DD.007763945E
67	05/26/2021	JUV	1470	600	R2R	Mark		3DD.003D560378
68	05/26/2021	JUV	1260	500	R2R	Mark		3DD.003D56034C
69	05/26/2021	JUV	1220	490	R2R	Mark		3DD.003D560392
70	05/26/2021	JUV	1110	430	R2R	Mark		3DD.003D560353
71	05/26/2021	JUV	770	330	R2R	Recapture	L17-20	3DD.0077A05F8D
72	05/26/2021	JUV			R2R	Recapture	L2	3D9.1C2CDACDE1
73	05/26/2021	M1-4	2340	870	R2R	Recapture	L2	3D9.1C2DC89230
74	05/26/2021	UNK	2080	810	R2R	Recapture	L2	3D9.1C2E0AAA13
75	05/26/2021	M5	1930	800	R2R	Mark		3DD.0077911617
76	05/26/2021	M5	2450	960	R2R	Mark	L2	3DD.00778F549B
77	05/26/2021	F5	2430	1110	Hatchery	Mark		3DD.0077915C95
78	05/26/2021	M5	2440	920	R2R	Recapture	L2	3DD.0077537673
79	05/26/2021	M5	2380	910	R2R	Recapture	L2	3D9.1C2DF5DEEA
80	05/26/2021	JUV			R2R	Recapture		3D9.1C2DF14F1B
81	05/26/2021	UNK	1880	760	R2R	Mark		3DD.0077915AA4
82	05/27/2021	JUV	1390	600	R2R	Recapture	L2	3D9.1BF10E26C4
83	05/27/2021	JUV	1320	540	R2R	Recapture	L2	3DD.0077614CF1
84	05/27/2021	JUV	550	200	R2R	Mark	L18-20	3DD.00779F62B3
85	05/27/2021	F5	2580	1160	Hatchery	Mark		3DD.007790DE9D
86	05/27/2021	M5	1540	790	R2R	Mark		3DD.0077904FDE
87	05/27/2021	F5	2850	1150	R2R	Mark		3DD.00779055AC
88	05/27/2021	M5	2410	910	R2R	Mark		3DD.00778F54ED
89	05/28/2021	F5	2630	980	R2R	Mark		3DD.00778F7BD2
90	05/28/2021	F3	2380	920	R2R	Mark		3DD.0077917EAD
91	05/28/2021	M5	2310	850	R2R	Mark	R8	3DD.0077907AA9

Appendix B
Agency Comments

From:	Jason McLellan (FNW)
To:	Deb Firestone
Subject:	RE: Grant PUD"s Draft 2021 White Sturgeon Management Plan Annual Report - For Review & Comment
Date:	Friday, February 18, 2022 1:38:06 PM
Attachments:	2022_02_09 GCPUD Draft 2021 WSMP Report CCT.pdf

Hi Deb,

Please find my suggested edits and comments on the 2021 White Sturgeon Management Plan Report.

Thanks,
Jason

From: Deb Firestone <Dfirest@gcpud.org>
Sent: Wednesday, February 9, 2022 12:36 PM
To: Aaron Jackson (AaronJackson@ctuir.org) <AaronJackson@ctuir.org>; Andrew Gingerich <andrewg@dcpud.org>; Breean Zimmerman <bzim461@ecy.wa.gov>; Carl Merkle <CarlMerkle@ctuir.com>; Donnella Miller <mild@yakamafish-nsn.gov>; Erin Harris <Eharris@gcpud.org>; Jason McLellan (FNW) <Jason.McLellan@colvilletribes.com>; Keith Hatch (keith.hatch@bia.gov) <keith.hatch@bia.gov>; Kirk Truscott (FNW) <Kirk.Truscott@colvilletribes.com>; Laura.Heironimus@dfw.wa.gov; Marcie Clement <Marcie.Clement@chelanpud.org>; Verhey, Patrick M (DFW) <patrick.verhey@dfw.wa.gov>; Ralph Lampman <lamr@yakamafish-nsn.gov>; RD Nelle <RD_Nelle@fws.gov>; Lewis, Stephen <Stephen_Lewis@fws.gov>; Tom Skiles (SKIT@critfc.org) <SKIT@critfc.org>; Tracy Hillman (Tracy.hillman@bioanalysts.net) <Tracy.hillman@bioanalysts.net>
Cc: Tom Dresser <TDresse@gcpud.org>; Shannon Lowry <Slowry@gcpud.org>; Chris Mott <Cmott@gcpud.org>; Mike Clement <Mclemen@gcpud.org>
Subject: Grant PUD's Draft 2021 White Sturgeon Management Plan Annual Report - For Review & Comment

Good afternoon,

Attached please find Grant County PUD’s 2021 draft White Sturgeon Management Plan annual report for a 30-day review and comment period.

Please provide your comments to me by March 9, 2022.

If you have questions regarding this report, please contact Mike Clement at Mclemen@gcpud.org or 509-750-3024.

Thanks!

Deb Firestone
Regulatory Specialist II – Environmental Affairs

OFFICE 509.793.1583
EXT. 2334
CELL 509.989.5824
EMAIL Dfirest@gcpud.org

grantpud.org

Please take care when opening links, attachments, or responding to this email as it originated outside of Grant.

Appendix C
Grant PUD's Response to Agency Comments

Submitting Entity	Date Received	Page #	Agency Comment	Grant PUD Response
Colville Confederated Tribes (J. McLellan)	2/18/2022	8	Was a 2L scute mark also applied?	Grant PUD has modified the appropriate text to indicate that mark applied to newly tagged fish.
	2/18/2022	32	Missing footnote	Grant PUD has modified and added the appropriate footnote to define the “unknown” sturgeon category in the table identified and other tables with that category
	2/18/2022	33	Missing footnote	Grant PUD has modified and added the appropriate footnote to define the “unknown” sturgeon category in the table identified and other tables with that category
	2/18/2022	35 p3	This is very concerning	Grant PUD agrees with this comment related to the reduction in the wild population estimate is a concern.
	2/18/2022	35 p4	This is very concerning	Grant PUD agrees with this comment related to the reduction in the wild population estimate is a concern.
	2/18/2022	49	What information supports this?	Grant PUD has modified this footnote to include the criteria used to identify unknown hatchery fish for which the brood year and stocking origin could not be determined. These unknown fish either did not have a PIT tag or had hatchery marks (three left lateral scutes removed) or obvious fin deformities common to hatchery fish. Fish captured that had a PIT tag, but not listed in PTAGIS or the project database, were also classified as unknown.
	2/18/2022	52	Seems high.	Grant PUD has modified this section to reflect a missing digit. The correct number was 0.051.
	2/18/2022	52	As well as the Tribal fishery?	Grant PUD agrees with the suggested edit and included the tribal fishery as a

				possible factor in the lower 2010BY survival estimate in Priest Rapids Reservoir.
	2/18/2022	65	Declines in wild fish following the fishery would not be categorized as a success.	Grant PUD generally agrees with the suggested edit and modified the sentence to indicate that the results of removal efforts were mixed, in that the 2002BY population was reduced, but that an inadvertent reduction of both the wild and 2010BY populations was also a result.
	2/18/2022	67	2011 or 2012. Both had high flow events.	Grant PUD generally agrees with the suggested edit and has modified the text to indicate that both 2011 and 2012 were very high flow years and that successful natural recruitment of White Sturgeon may have occurred in these years.
	2/18/2022	67	Exactly, so the effort was not a success and has done more harm than good.	Grant PUD generally agrees with the suggested edit and has modified the text reference on page 77 to reflect this comment.

Appendix D
Washington Department of Ecology's Approval Letter

STATE OF WASHINGTON

DEPARTMENT OF ECOLOGY

1250 W Alder St • Union Gap, Washington 98903-0009 • (509) 575-2490
711 for Washington Relay Service • Persons with a speech disability can call 877-833-6341

March 15, 2022

Mr. Tom Dresser
Fish, Wildlife and Water Quality Manager
Grant County PUD
PO Box 878
Ephrata, WA 98823

RE: Request for Ecology Review and Comments – *2021 White Sturgeon Management Plan Annual Report*
Priest Rapids Hydroelectric Project No. 2114

Dear Mr. Dresser:

The Department of Ecology (Ecology) has reviewed the *2021 White Sturgeon Management Plan Annual Report* sent via email to Ecology on February 9, 2022.

Ecology has **no comments** for the *2021 White Sturgeon Management Plan Annual Report*. This report is a requirement of Section 6.2(5)(d) for the *White Sturgeon Management Plan* of the 401 certification.

Please contact me at (509) 575-2808 or breean.zimmerman@ecy.wa.gov if you have any questions.

Sincerely,

Breean Zimmerman

Breean Zimmerman
Hydropower Projects Manager
Water Quality Program

ec: Chris Mott, Grant County PUD