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Science Response 2024/025

INFORMATION FOR REFINING CANDIDATE CRITICAL HABITAT OF WHITE STURGEON (*ACIPENSER TRANSMONTANUS*), UPPER COLUMBIA RIVER POPULATION

Context

In Canada, White Sturgeon (*Acipenser transmontanus*) is found in rivers and lakes within the Fraser, Nechako, Columbia, and Kootenay river systems in British Columbia (BC). White Sturgeon is the largest (max length 6.10 m) freshwater fish species in Canada, with a lifespan that can exceed 100 years (Scott and Crossman 1998; McPhail 2007). The Upper Columbia River population of White Sturgeon is a designatable unit (DU) recognized as at-risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Recovery of the White Sturgeon, Upper Columbia River population or DU, is impeded by recruitment failure due to habitat changes, predominantly related to dams and river regulation (DFO 2014, 2023a; McAdam 2015). Other threats include direct and indirect alterations to habitat (e.g., instream activities; development of riparian, foreshore, and floodplain areas), incidental mortality, and ecosystem changes (e.g., invasive species; Hatfield et al. 2013; DFO 2014, 2023a).

Recovery efforts for White Sturgeon in the Upper Columbia River began in 2000 with the establishment of the Upper Columbia White Sturgeon Recovery Initiative (UCWSRI), a coordinated transboundary Technical Working Group (TWG) formed to provide scientific advice, to develop plans to guide recovery of the species, and to oversee implementation and monitoring of these plans in cooperation with the responsible agencies. Albeit not being official documents under the *Species at Risk Act* (SARA 2002) in Canada, the UCWSRI TWG developed the original recovery plan in 2002, updated in 2012 (Hildebrand and Parsley 2013), which provides broad recovery objectives covering both the Canadian and United States (US) portions of the recovery area.

In Canada, White Sturgeon were assessed by COSEWIC as six nationally significant populations in 2003, with the Upper Columbia River DU of White Sturgeon assessed as Endangered. This COSEWIC (2003) assessment subsequently led to the White Sturgeon, Upper Columbia River population, being listed under Schedule 1 of SARA as Endangered in 2006. In 2012, the COSEWIC reassessment revised the population structure and identified four White Sturgeon DUs and again assessed the Upper Columbia River DU as Endangered (COSEWIC 2013). Following the SARA listing in 2006, a federal Recovery Strategy (DFO 2014, 2023a) was produced that identified White Sturgeon critical habitat.

Critical habitat is defined in SARA as "*…the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in a recovery strategy or in an action plan for the species*" [s. 2(1)]. Under SARA S.41.1(c) a species' critical habitat must be identified "*…to the extent possible, based on the best available information, including the information provided by COSEWIC, and examples of activities that are likely to result in its destruction.*" At the time of original critical habitat identification for White Sturgeon, spawning within the Kinnaird reach (downstream of the Kootenay-Columbia River confluence) had only recently been detected and therefore evidence was deemed insufficient to support its inclusion as critical habitat. Nevertheless, the White Sturgeon Recovery Strategy (DFO 2014, 2023a), Action Plan (DFO 2023b), and Hatfield et al. (2013), assessed the Kinnaird reach of the Columbia River as important habitat since spawning had been recently observed. In line with the recommended schedule of studies in the recovery strategy (DFO 2014, 2023a), research and monitoring efforts on White Sturgeon in the Kinnaird reach of the Columbia River have increased, and the area appears to support all life stages (BC Hydro 2023a, 2023b).

Fisheries and Oceans Canada (DFO) Species at Risk Program has requested science advice to support the refinement of additional candidate critical habitat for White Sturgeon, Upper Columbia River population, using data from recent monitoring efforts in the Kinnaird reach. The assessment and advice arising from this Canadian Science Advisory Secretariat (CSAS) Science Response process will be used by the Species at Risk Program to ensure critical habitat is properly identified to the greatest extent possible and protected for White Sturgeon, Upper Columbia River population. Existing critical habitats for the DU are not being considered in this review.

The specific objectives of this review are to:

1. Review information available from the Kinnaird reach on the habitat necessary for survival and recovery of White Sturgeon, Upper Columbia River population.
2. Update the functions, features, and attributes of the habitat across life stages.
3. Present updated candidate critical habitat spatial attributes for the Kinnaird reach.

This Science Response Report results from the January 11, 2024 regional peer review on the Information for Refining Candidate Critical Habitat for White Sturgeon (*Acipenser transmontanus*), Upper Columbia River Population.

Background

Recruitment of White Sturgeon in the Upper Columbia River was substantially reduced with the completion of large mainstem dams about 50 years ago (McAdam 2015), and the wild-origin population has been declining since then (Hildebrand et al. 2016). This trend is consistent with that of the species, with White Sturgeon declining throughout their range (Crossman and Hildebrand 2022). Recovery actions for White Sturgeon in the Upper Columbia River have included substantial research and monitoring efforts in Canada and the US to understand the mechanisms associated with recruitment failure in the population and describe population demographics (Hildebrand and Parsley 2013). Results from this work have been fundamental in determining the effectiveness of conservation actions and in identifying areas where additional actions or protections may provide biological benefit or stimulate natural recruitment.

Critical habitat was identified for White Sturgeon, Upper Columbia River population to the extent possible in the 2014 Recovery Strategy (DFO 2014, 2023a) using information provided in Hatfield et al. (2013). It was acknowledged that ongoing monitoring was required to address data gaps that existed for most life stages (Hatfield et al. 2013). In particular, locations used by early life stages were considered a priority as the recruitment bottleneck in the population has been identified between 0–40 days post hatch (Hildebrand and Parsley 2013).

Identification of spawning locations and describing the duration and frequency of spawning activity have been important components of the recovery program. Prior to 2007 when the original critical habitat identification process began, studies had identified White Sturgeon spawning sites at two primary locations at the confluence of the Columbia and Pend d’Oreille rivers in Canada (Waneta, river kilometer (rkm[1]) 56.0) and in the vicinity of Northport, Washington in the United States (Howell and McLellan 2006). The Waneta spawning site is currently protected under the *Critical Habitat of the White Sturgeon (*Acipenser transmontanus*) Upper Columbia River Population Order*, SOR/2016-85. Additional monitoring in Canada identified spawning at the area immediately downstream of Hugh L. Keenleyside (HLK) Dam and Arrow Lakes Generating Station (ALH, rkm 0.1; BC Hydro 2013), and in the Kinnaird reach (rkm 13.0 to 20.0; Golder 2008). These results demonstrated that undocumented spawning locations remained and emphasized the importance of continued monitoring to describe adult reproductive ecology, determine mechanisms influencing spawning site selection, and understand underlying mechanisms resulting in recruitment failure. Despite limited information at the time, the ALH spawning site was included as protected critical habitat since it was already within an area being protected for other reasons (feeding, staging, and overwintering). The Kinnaird reach was identified as an area where substantial uncertainty remained (Hatfield et al. 2013), even though available information suggested it was used by all life stages (Hildebrand and Parsley 2013). It was not included in the final list of critical habitats protected but was identified as an important area for further study (DFO 2014, 2023a).

A conservation aquaculture program was implemented in 2001 as a temporary action to prevent extirpation of the population by restoring a natural age structure and retaining the genetic diversity of the existing wild-origin population (Hildebrand and Parsley 2013). The program has been successful in restoring over 20 year classes in the population and led to an increased abundance of White Sturgeon throughout the entire Canadian section of the river (Crossman et al. 2023). Research and monitoring on habitat use has been ongoing for both wild-origin and hatchery-origin White Sturgeon, demonstrating more widespread use of habitats throughout the river compared to when the population was first listed under SARA (BC Hydro 2023a, 2023b; Jetter 2022). More recently the conservation aquaculture program has transitioned to sourcing progeny from natural spawning events in the wild in order to improve genetic diversity of progeny for release into the population. This includes incorporation of progeny from all known spawning sites in the Canadian section, including the Kinnaird reach. Research to describe the reproductive structure of the hatchery-origin segment within Kinnaird reach has identified that a portion of males are capable of spawning (Maskill et al. 2022; BC Hydro 2023b) and pre-vitellogenic (early ovarian development; Webb et al. 2019) females (BC Hydro 2023b) are also present. With additional spawners entering the population, spawning habitats require protection to ensure recovery progresses until uncertainties related to recruitment failure are resolved.

Analysis and Response

When an aquatic species is listed on Schedule 1 of SARA as Threatened, Endangered or Extirpated, DFO is required to identify and protect the species' critical habitat, to the extent possible based on the best available information. Critical habitat is defined under SARA as "*the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species*". Further, habitat of aquatic species is defined as "*spawning grounds and nursery, rearing, food supply, migration, and any other areas on which aquatic species depend directly or indirectly to carry out their life processes, or areas on which aquatic species formerly occurred and have the potential to be reintroduced*". Critical habitat is typically identified in the species' recovery strategy and linked to the species' population and distribution objectives.

[1] River kilometers are measured moving downstream from Hugh L. Keenleyside Dam (HLK; rkm 0) to the international border with the US (rkm 57.0).

Although critical habitat for White Sturgeon was identified to the extent possible in the recovery strategy (DFO 2014, 2023a), a “Schedule of Studies to Identify Critical Habitat” lists further research necessary to identify and/or refine additional critical habitat. Confirmation of habitat use by various life stages of White Sturgeon in the Kinnaird reach of the Columbia River was listed as a study necessary to refine critical habitat (DFO 2014, 2023a). Per DFO guidance on critical habitat identification, scientific information on the Kinnaird reach to refine candidate critical habitat should include the geographic location (e.g., coordinates); functions, features, and attributes; and a summary of habitat identification relative to population and distribution objectives[2]. This Science Response provides a review of updated and available data from the Kinnaird reach of the Columbia River that will be used to inform the refinement of critical habitat under SARA.

Information and methods used to refine candidate critical habitat

The intent of this Science Response is to provide information on important habitat in support of the refinement of critical habitat. The information was derived from the Recovery Potential Assessment (RPA; Wood et al. 2007), Hatfield et al. (2013), guidance for critical habitat identification[2], the Recovery Strategy (DFO 2014, 2023a), and field data collected between 2007−2022.

The approach used to delineate the candidate critical habitat for White Sturgeon, Upper Columbia River population is the parcel approach. The parcel approach defines an area with specific candidate critical habitat features[2]. The parcel approach is applied when there is detailed knowledge of the habitat’s features and attributes that support the species’ life cycle functions and the locations of the features remain stable over time and can be mapped[2].

Response to Objective 1: Review information available from the Kinnaird reach

The Kinnaird reach was evaluated using results from research and monitoring activities for use by each White Sturgeon life stage (Golder 2008; BC Hydro 2013a, 2013b, 2015, 2016, 2018, 2023a; Hildebrand and Parsley 2013; Jay et al. 2014; Crossman et al. 2016, 2023). Life stage descriptions and life stage specific habitat requirements remain consistent from the prior assessment of critical habitat for this population (Hatfield et al. 2013) and the recovery strategy (DFO 2014, 2023a).

Use of the Kinnaird reach for spawning and early life stage rearing

Monitoring to determine if spawning was occurring in this reach was piloted in 2007 and was based on evidence from adults with telemetry transmitters making movements to the area during the known spawning period in June and July (Golder 2008). Following the capture of a yolk-sac larvae in July of 2007, annual monitoring was initiated to identify the timing and frequency of spawning days in the Kinnaird reach using egg mats and drift nets to collect White Sturgeon embryos and larvae (detailed methods described in BC Hydro 2013a, 2013b). The use of egg mats and drift nets is a standard approach for monitoring sturgeon spawning activity (Haxton et al. 2023). Egg mats provide a passive approach to collecting embryos deposited during spawning events and can be deployed continuously across the spawning season. Drift nets can be more effective compared to egg mats as they capture displaced embryos or dispersing larvae downstream of spawning locations but have to be deployed for shorter durations as they can quickly fill with detritus/debris in the water, reducing survival of collected embryos or larvae. Sampling effort that included a combination of egg mats and drift nets was

[2] DFO. 2015. Guidelines for the Identification of Critical Habitat for Aquatic Species at Risk. Unpublished Report, Ecosystem Management Branch, Ottawa, Canada, 43 p.

applied consistently over the period of 2007−2022, with the exception of 2012 where peak flows were well above average, which reduced overall effort and the number of locations where equipment could be safely deployed. Spawning was detected through either embryo or larval captures in 13 of 16 years of monitoring (Table 1; BC Hydro 2023a). Additional telemetry analysis incorporating daily detection data from 2008–2017 showed a proportion (40%) of tagged mature adults (n=124) made movements to the Kinnaird reach during the period when spawning was identified to have occurred (BC Hydro 2018). The exact location(s) of embryo deposition remain uncertain as numbers of embryos (n=12) and larvae (n=114) collected have been low (Table 1) relative to other spawning areas for this population monitored with the same methods (e.g., Waneta; BC Hydro 2023a), with >90% of the samples collected as yolk-sac larvae. Distribution of embryo and larval captures has occurred between rkm 14.5 and rkm 18.2. Spawning in the Kinnaird reach has occurred from as early as June 24 through August 9, with an average of 2.6 spawning events (range 1–6 events) in years where spawning was detected (Table 1; BC Hydro 2023a). Temperatures during the spawning period have ranged between 13.0–19.2°C (Figure 1), which is in the optimal range for survival based on research investigating development at embryo (Wang et al. 1985; 1987) and larval (Jay et al. 2020) stages. Genetic analysis of parentage conducted on progeny collected in 2011 estimated 32 spawning adults (95% CI:19–58) contributing to offspring at the Kinnaird reach, representing 19% of the total estimated spawning adults in the Canadian section in that year across all spawning sites combined (Jay et al. 2014).

Captures of embryos and larvae have occurred in sampling equipment deployed downstream of the Highway 3 bridge in Castlegar, suggesting spawning is occurring between rkm 13.0–19.0, where a consistent downstream location has been sampled since 2009. The highest upstream point of embryo or larval capture has been rkm 14.5, which is why an upstream buffer was included up to rkm 12.0 to include a set of rapids that may provide suitable embryo deposition habitat. Larvae passively dispersing past the downstream sampling site at rkm 19.0 encounter a reach starting at rkm 20.0, adjacent to Blueberry Creek, with areas of slower water velocities and finer substrates. After rkm 20.0 habitat use for early life stages is uncertain as no sampling has been conducted. Accordingly, rkm 20.0 is proposed as the downstream boundary for critical habitat in the Kinnaird reach based on available information.

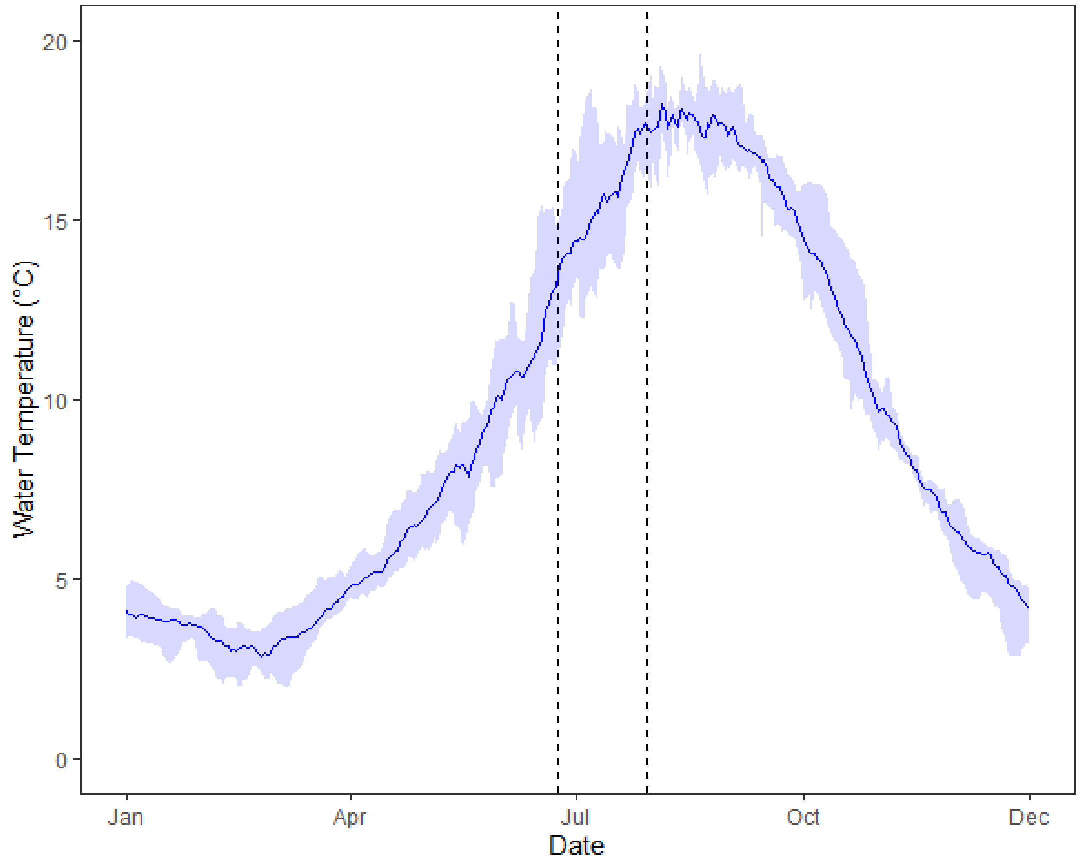

Figure 1. Mean daily temperatures (°C) for the Kinnaird reach measured at rkm 13.0 on the Columbia River, 2015–2022. The shaded area represents the 10th and 90th quantiles of the temperature data over the same period. The vertical dashed lines represent the White Sturgeon spawning period observed in the Kinnaird reach between 2007–2023 (BC Hydro 2023a).

Table 1. Years where spawning was detected in the Kinnaird reach, the number of embryos and larvae captured, the estimated number of days with spawning events, and the spawning period date range. Spawning events are the fertilization date for collected embryos and larvae, estimated by back-calculation from the recorded date and time of capture/preservation based on developmental stage and mean incubation water temperature.

Year	Embryos	Yolk-sac Larvae	Spawning Days	Start of Spawning	End of Spawning	Citation
2007	0	1	1	17-Jul-07	19-Jul-07	Golder 2008
2008	0	1	1	10-Jul-08	11-Jul-08	Golder 2009
2009	0	5	1	19-Jul-09	20-Jul-09	BC Hydro 2013a
2010	1	8	3*	14-Jul-10	01-Aug-10	BC Hydro 2013a
2011	2	32	n/a**	26-Jul-11	09-Aug-11	BC Hydro 2013b; Jay et al. 2014
2012***	0	0	0	-	-	BC Hydro 2015
2013	0	5	2	23-Jul-13	27-Jul-13	BC Hydro 2023a
2014	6	13	3	14-Jul-14	22-Jul-14	
2015	0	8	4	02-Jul-15	09-Jul-15	
2016	0	17	6	03-Jul-16	30-Jul-16	
2017	1	14	1	10-Jul-17	10-Jul-17	
2018	0	4	4	05-Jul-18	13-Jul-18	
2019	1	6	4	24-Jun-19	23-Jul-19	
2020	0	0	0	-	-	
2021	0	0	0	-	-	
2022	1	0	1	11-Jul-22	11-Jul-22	

* Minimum number of events due to degraded samples for developmental staging.

** Samples preserved for parentage analysis (Jay et al. 2014) and not developmentally staged. Duration of spawning reflects the period when embryos and larvae were collected.

*** High flow year with limited sampling effort.

Use of the Kinnaird reach by juveniles, sub-adults, and adults

Sampling for juveniles and adults in the Kinnaird reach has occurred intermittently since the late 1990s. For this candidate critical habitat review, we incorporated individual records between 2007–2022 for fish captured within the spatial boundaries of the Kinnaird reach as described above. During this period, semi-annual monitoring has been conducted in a systematic and spatially balanced design. Generally, sampling effort for direct captures was conducted using baited setlines for fish capture (Hildebrand and Parsley 2013; Crossman et al. 2023), with recaptures contributed from other supplemental methods (e.g., gillnets and angling) in certain years. In addition to direct capture efforts, a long-term passive acoustic telemetry array has been maintained in the Upper Columbia River to describe year-round movements and habitat use.

Results from capture efforts demonstrate juveniles, sub-adults, and adults use habitats throughout the entire Kinnaird reach, with substantial annual captures of both hatchery-origin and wild-origin White Sturgeon (Figure 2) during spring and fall sampling sessions. Importantly, one of the few wild-origin juveniles (<3 years of age) detected from wild recruitment in the last decade was collected in the Kinnaird reach (Figures 2 and 3; BC Hydro 2015). Capture data has identified hatchery-origin White Sturgeon's use of the Kinnaird reach for 14 distinct year classes, with ages of those fish distributed from 1 to 20 years of age following release from the hatchery. Sex and stage of maturity was assigned to adults during capture efforts (following Webb et al. 2019) and a number of males and females were in spawning condition, demonstrating use of the Kinnaird reach for staging prior to spawning (Figure 4). In addition to the capture records, results from acoustic telemetry studies found that a portion of individual adult White Sturgeon (13%) spent > 75% of their time year-round in the Kinnaird reach over a 10-year period (n=99 adults with active tags distributed in the entire Canadian section; BC Hydro 2016). This high site fidelity is similar to other reaches in the Canadian section, where individual adults select specific habitats for year-round use, suggesting that habitat protections in one area may not benefit all individuals in the population equally. Detections from all acoustically tagged adults in the Canadian section found 21% of fish spent a minimum of 25% of their time in the Kinnaird reach, with the remaining tagged adults in the population transitioning through the reach for feeding or to migrate to spawning areas (BC Hydro 2016). More comprehensive analyses of both juvenile and adult habitat use within Kinnaird reach is ongoing (BC Hydro, unpublished data).

Given year-round habitat use has been identified, the Kinnaird reach serves as an important feeding area for juveniles, sub-adults, and adults, and this was identified in the original critical habitat assessment (Hatfield et al. 2013). Research to describe benthic prey availability in the Kinnaird reach shows available food of the appropriate type for juvenile life stages that aligns with diet preferences in other areas of the river (Crossman et al. 2016). In addition to benthic prey, sub-adults and adults also feed on fish such as Rainbow Trout (*Oncorhynchus mykiss*) and Mountain Whitefish (*Prosopium williamsoni*), which are both distributed throughout the Kinnaird reach (Golder et al. 2021). The number of White Sturgeon observed over Rainbow Trout redds in the Canadian section of the Columbia River has been increasing in the past 20 years (Amies-Galonski and Thorley 2018). White Sturgeon are an opportunistic feeder known to take advantage of seasonally abundant food sources where available (DFO 2014, 2023a), and it is assumed that sturgeon are either excavating and consuming Rainbow Trout embryos from redds or they are consuming adult spawners. Spawning Rainbow Trout distribute redds throughout the Kinnaird reach (Baxter et al. 2023) and Rainbow Trout of multiple life stages likely serve as an important year-round food source. Anecdotal evidence from anglers in the Kinnaird reach also provides support for active predation of Rainbow Trout by adult White Sturgeon (M. Marrello, BC Hydro, personal communication, 2023).

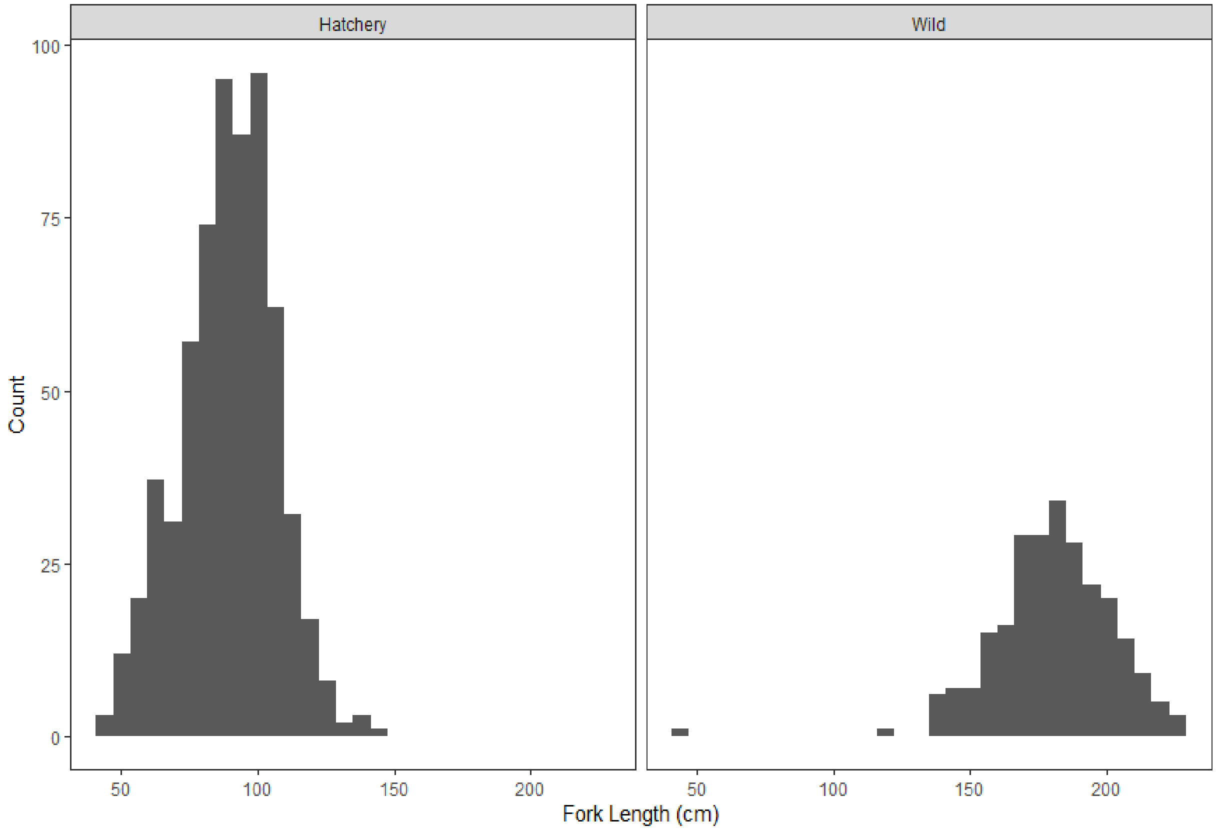

Figure 2. Length frequency of hatchery-origin and wild-origin White Sturgeon captured during semi-annual monitoring conducted in the Kinnaird reach between 2007–2022 (BC Hydro, unpublished).

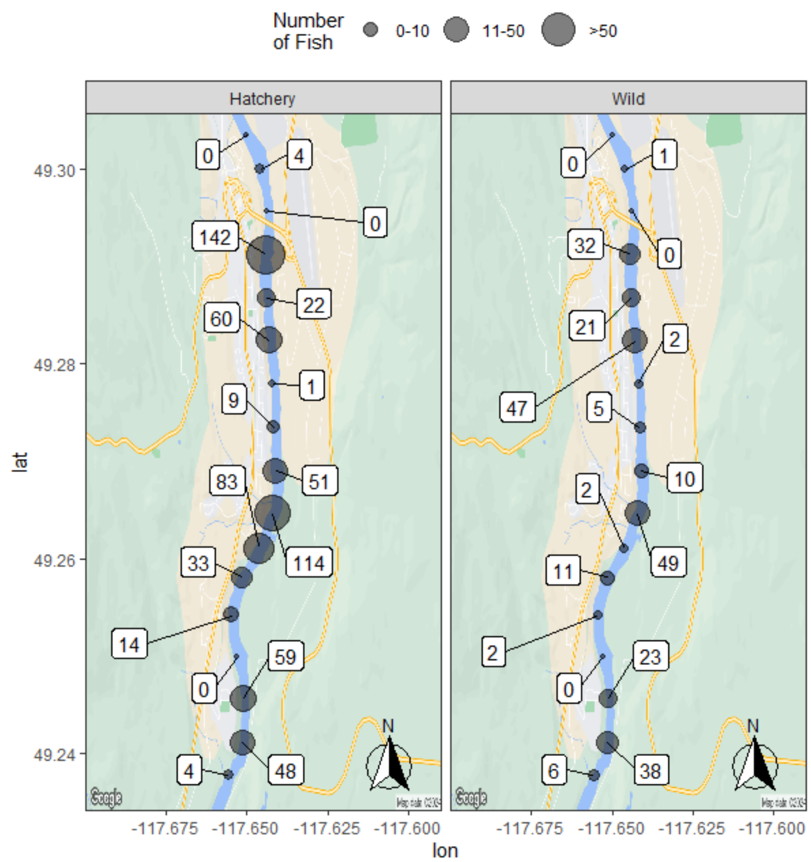

Figure 3. Locations of hatchery-origin and wild-origin White Sturgeon captured in the Kinnaird reach of the Upper Columbia River between river kilometer 12.0 and 20.0 during annual monitoring between 2007–2022 (BC Hydro, unpublished).

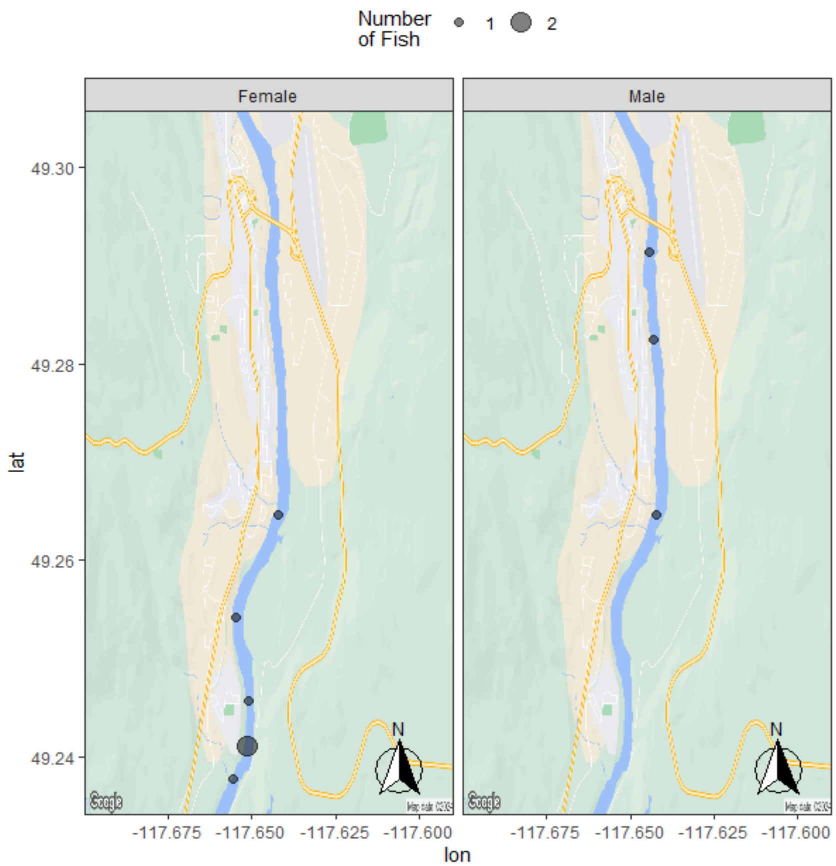

Figure 4. Locations of staging female and male wild-origin White Sturgeon captured in the Kinnaird reach of the Upper Columbia River between river kilometer 12.0 and 20.0 between 2007–2022 (BC Hydro, unpublished). Females include those staged as late vitellogenic (stage 4; Webb et al. 2019) to post vitellogenic (stage 5) and males were staged as those that were mature (stage 5) or actively spermiating (stage 6; Webb et al. 2019).

Habitat description

The habitat in the Kinnaird reach is primarily areas of faster water velocities with deeper back eddies between 10–20 m in depth. White Sturgeon juveniles, sub-adults, and adults predominantly select deeper habitats with slower water velocities (< 1.0 m/s; DFO 2023b), and the distribution of captures reflects this with White Sturgeon encountered in all areas of slower water (Figure 2). The faster reaches (> 1.5 m/s) within Kinnaird serve as feeding, spawning, and transitionary habitats. Discharge through the Kinnaird reach is a combination of regulated flows from the Columbia River (Arrow Lakes Reservoir) and the Kootenay River (Brilliant Dam). Timing of freshet is earlier in the Kootenay River compared to the Columbia River, resulting in a period of sustained higher flows in the summer with two peaks (Figure 5). Water velocities during the spawning period are within the suitable range for White Sturgeon with > 1.5–2.0 m/s in the thalweg and < 2.0 m/s on the margins of the eddies and thalweg (BC Hydro unpublished data). Transects conducted with an acoustic doppler current profiler (ADCP) during the spawning period found mean water velocities (+/- 1 SD) in the Kinnaird reach of 1.82 +/- 0.07 m/s during a high flow year in 2012 and 1.76 +/- 0.03 m/s during a typical flow year in 2011 (BC Hydro, unpublished data). The temperature profile in the Kinnaird reach is within the suitable range for the species, with spawning temperatures reaching 14.0°C by late June

(Figure 1) and not exceeding the 20°C threshold, which is negatively associated with early life stage survival and development (Wang et al. 1985; Parsley et al. 2011; Boucher et al. 2014).

As part of a project to determine feasibility of spawning substrate restoration, a comprehensive habitat survey was conducted by West et al. (2020) to describe current conditions in the Kinnaird reach. Results found the dominant substrate was boulder and cobble. Substrate embeddedness within the Kinnaird reach was generally low, but highly variable with pockets of fines present throughout. However, areas of fine materials were much smaller in comparison to the ALH and Waneta spawning areas, and embeddedness was more directly associated with substrate compaction rather than the deposition of fines. Habitat suitability in the Kinnaird reach was assessed by applying the White Sturgeon habitat recruitment model developed by Hatten et al. (2018) for the Columbia River below Bonneville Dam where annual recruitment occurs. Results identified large areas within the Kinnaird reach as being suitable habitat under present conditions (West et al. 2020). While restoration alternatives for the Kinnaird reach were considered, none were developed as there was uncertainty surrounding spawning and rearing locations and the feasibility of construction in deeper habitats with fast water velocities. Spawning substrate restoration has recently been completed within the critical habitat at the ALH spawning area (BC Hydro, unpublished), and results from effectiveness monitoring will help to inform actions that can be implemented at other spawning areas like the Kinnaird reach.

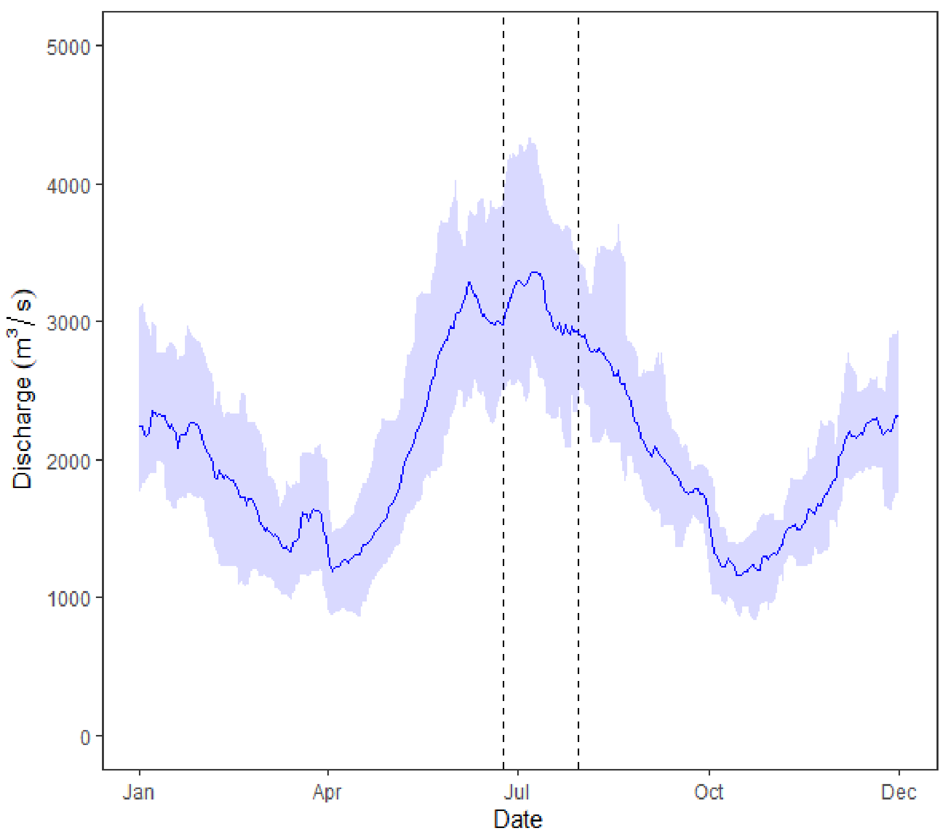

Figure 5. Mean daily discharge (m^3/s; dark blue line) for the Kinnaird reach measured at the Birchbank gauging station on the Columbia River, 2007–2022. The shaded area represents the 10th and 90th quantiles of the discharge data over the same period. The vertical dashed lines represent the White Sturgeon spawning period observed in the Kinnaird reach between 2007–2022 (BC Hydro 2023a).

Response to Objective 2: Update the functions, features, and attributes

Table 2. Summary of the functions, features, and attributes for each life stage of White Sturgeon specific to the Kinnaird reach. Kinnaird reach is defined as river kilometer (rkm) 12.0 on the Columbia River (upstream of the Highway 3 bridge) to rkm 20.0 near Blueberry Creek. River kilometers are measured moving downstream from Hugh L. Keenleyside Dam near Castlegar, British Columbia. Table modified from DFO (2023a).

Life Stage(s)	Function(s)	Feature(s)	Attribute(s)
Egg and Embryo	Nursery, incubation	• Benthic zone	• Coarse substrates, gravel to cobble providing interstitial spaces for incubation • Incubation occurs within optimal water temperature between 14–18°C • Wetted conditions required; embryos are unable to leave the area at this stage
Yolk Sac Larva (0–12 days post-hatch)	Rearing	• Benthic zone	• Coarse substrates, gravel to cobble providing interstitial spaces for shelter, which improves growth, development, and survival • Water temperatures are suspected to be optimal for growth and development between 14–18°C • Wetted conditions required; yolk sac larvae are unable to leave the area at this stage
Feeding Larva (12–40 days post-hatch)	Rearing, growth, and feeding	• Lotic environment • Eddy • Food supply • Benthic zone	• River thalweg habitat used for passive larval dispersal and includes faster water velocities >1.5 m/s • Dispersal zones downstream of spawning sites that provide appropriate fine sediments and prey • Water temperatures are suspected to be optimal for feeding larvae between 14–18°C • Source of benthic invertebrates • Feeding larvae may still require coarse substrates, gravel to cobble providing interstitial

Life Stage(s)	Function(s)	Feature(s)	Attribute(s)
			spaces for shelter in addition to areas of finer sediment like silt and sand
Early Juvenile (40 days to 2 years post-hatch)	Rearing, growth, and feeding	• Benthic zone • Food supply	• Source of benthic invertebrates and/or small benthic dwelling fish • Depths > 2 m • 0.1–1.2 m/s mean column velocity, and near-substrate velocity of 0.1–0.8 m/s
	Overwintering	• Pools • Depositional area	• Generally, depths > 5.0 m, however, shallower depths may be used • Lower velocity areas, < 1.0 m/s
Late Juvenile and Adult (> 2 years)	Feeding, resting	• Lotic environment • Depositional area • Food supply	• Lower velocity areas where fish can rest and prey species may congregate; often in close proximity to confluences with other water bodies providing further access to food sources • Opportunistic feeders that consume fish, preferably salmonids, and invertebrates • Deeper water areas > 15 m that have lower velocities relative to mainstem flows
	Overwintering	• Pools • Depositional area	• Generally depths > 5.0 m, however, shallower depths may be used • Lower velocity areas, 0.5 m/s
Adult	Staging	• Pools	• Deep (> 5 m), low velocity (< 1.0 m/s) habitat with ability to access higher velocity areas
	Spawning	• River thalweg • Benthic zone	• Coarse substrates, gravel to cobble providing interstitial spaces for embryos • Water temperature 13–19.2°C • Mean water column velocities at most spawning sites are > 0.8 m/s • Thalweg depths of 4–5 m

Response to Objective 3: Candidate critical habitat spatial attributes for the Kinnaird reach

For White Sturgeon, Upper Columbia River population, refined candidate critical habitat in the Kinnaird reach is identified to the extent possible, using the best available information, and provides the functions and features necessary to support the species across all life stages and life cycle processes. Based on all the functions, features, and attributes, the refined candidate critical habitat is defined as the Kinnaird reach in the Upper Columbia River from rkm 12–20. The elevational boundary is limited to the high water mark of the river (Hatfield et al. 2013). To use the parcel approach for refining the candidate critical habitat, the following coordinates are recommended (Table 3, Figure 6).

Table 3. Geographical coordinates for refined candidate critical habitat for White Sturgeon, Upper Columbia population, in the Kinnaird reach. River kilometer (rkm) is measured moving downstream from Hugh L. Keenleyside Dam near Castlegar, British Columbia.

Location description	Latitude	Longitude
Upper extent, west bank (rkm 12.0)	49.3034833	-117.6522359
Upper extent, east bank (rkm 2.0)	49.30362282	-117.6478222
Lower extent, west bank (rkm 20.0)	49.2377839	-117.6579133
Lower extent, east bank (rkm 20.0)	49.2376077	-117.654316

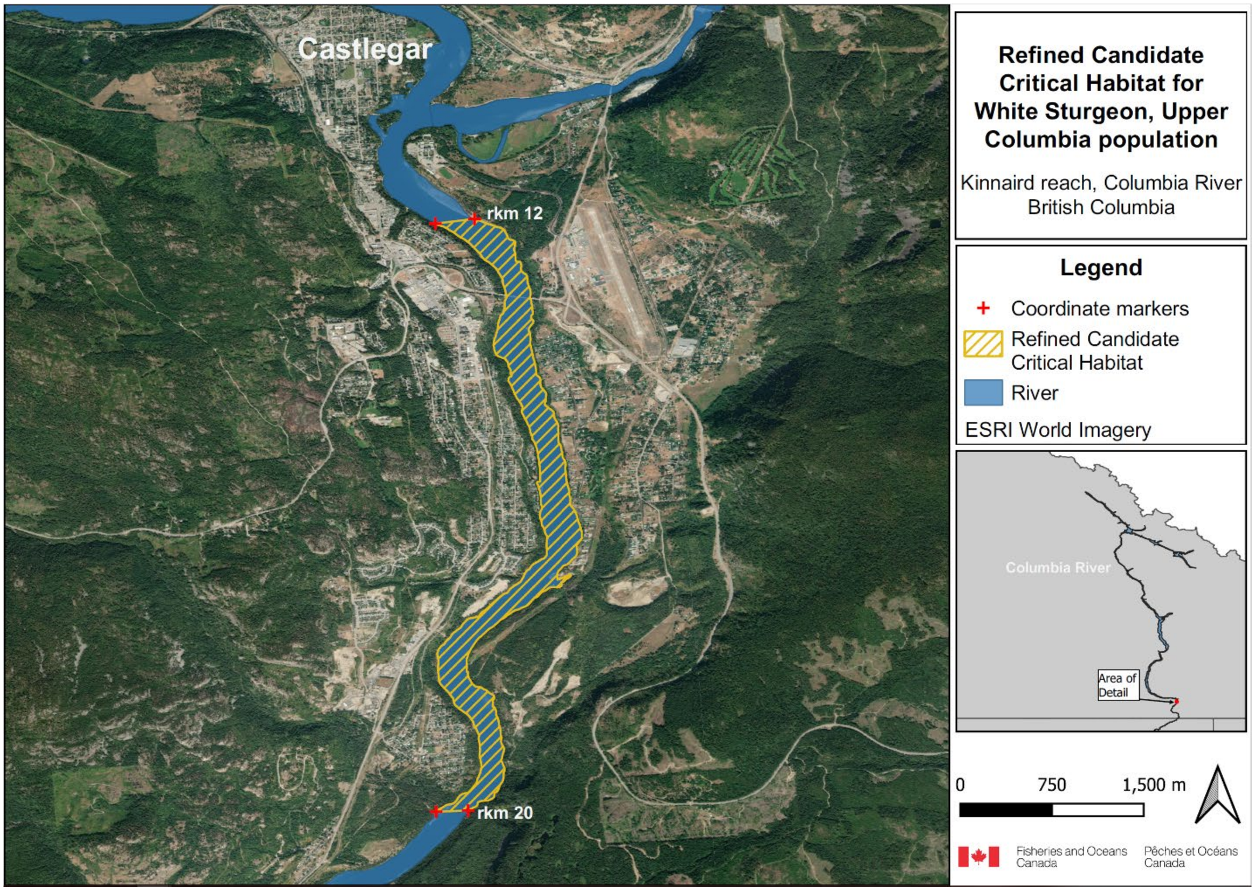

Figure 6. Refined candidate critical habitat for White Sturgeon, Upper Columbia River population in the Kinnaird reach of the Columbia River, British Columbia. The upper boundary of the polygon is at rkm 12 and the lower boundary is at rkm 20. River kilometers (rkm) are measured moving downstream from Hugh L. Keenleyside Dam in Castlegar (rkm 0) to the international border with the US (rkm 57.0). See Table 3 for geographical coordinates of polygon.

Conclusions

The original critical habitat assessment identified the Kinnaird reach as an important habitat given use of the area by all life stages. Subsequent monitoring results further support its inclusion as candidate critical habitat, as it is used year-round for overwintering, staging, feeding, spawning, and for incubation and development of early life stages. In particular, detection of early life stages (0–40 days; embryo and larvae) almost annually over a 16-year period is an important result as these life stages are the key recruitment bottleneck in this population and therefore a high priority for conservation. Functions, features, and attributes in the Kinnaird reach of the Upper Columbia River were outlined to refine candidate critical habitat. Furthermore, coordinates were provided to calculate a candidate parcel for the Kinnaird reach based on the updated information.

Uncertainties remain about the exact location(s) of egg deposition and embryo incubation because embryos and larvae have been collected at multiple sampling sites throughout the Kinnaird reach. This suggests the location adult White Sturgeon are choosing to spawn may change depending on environmental conditions (e.g., flow patterns; Figure 5) within a given year. Additional monitoring of spawning activity will be important, especially as additional hatchery-origin fish potentially increase the number of embryos deposited. Methods for

describing detailed information on broadcast spawning species in large rivers are challenging. Multiple approaches should continue to be used in the Kinnaird reach that allow for fine-scale identification of spawning habitat. This may include methods to directly document spawning through early life stage captures (e.g., egg mats and drift nets) supplemented by indirect methods that provide more fine-scale information of adult spawner distribution (e.g., telemetry and sidescan sonar). Additionally, monitoring should include sampling that occurs downstream of the Kinnaird reach to document the extent of larval dispersal in years when spawning is detected. Water temperatures are within the ideal range, especially compared to the primary spawning site at Waneta where temperatures have been shown to rapidly exceed 20°C during the spawning period in recent drier years (BC Hydro 2023a). Accordingly, the Kinnard reach could become an increasingly important area for early life stages. It is uncertain how climate change may influence environmental conditions for sturgeon and further research on this topic remains important (e.g., Earhart et al. 2023), in particular thermal and habitat preferences for the feeding larval stage. While there are large sections of suitable spawning habitat in the Kinnaird reach, opportunities for restoration should continue to be evaluated as more information on spawning locations is collected. In addition to monitoring spawning activity, continued evaluation of habitat use within the Kinnaird reach remains important.
A comprehensive analysis of the long-term movements and habitat use within the Kinnaird reach and the entire Canadian section of the Columbia River is ongoing with results expected in 2024 (BC Hydro unpublished data).

Riparian habitat was not included as part of the candidate critical habitat in the Kinnaird reach, but is expected to provide ecosystem functions to the area through contributions to primary productivity, maintaining physical attributes of the river, among others (DFO 2020). Further, in the Columbia River, removal of riparian areas can change the habitat's structure and cover, which can alter the attributes necessary for the survival or recovery of White Sturgeon (DFO 2014, 2023a). Future studies are needed to better understand the contribution of riparian habitat functions on the Columbia River, and particularly in the Kinnaird reach for the survival or recovery of White Sturgeon. If new information alters our current understanding this may result in amending candidate critical habitat.

The largest remaining uncertainty for this population is the mechanism(s) contributing to recruitment failure and identifying actions to address them. While positive outcomes from conservation actions have been documented, resolving continued natural recruitment failure should remain a clear objective with protection of critical habitat as a key component of recovery.

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